metal finishing

APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING, ANIZING, METAL SPRAYING and all METAL FINISHING PROCESSES

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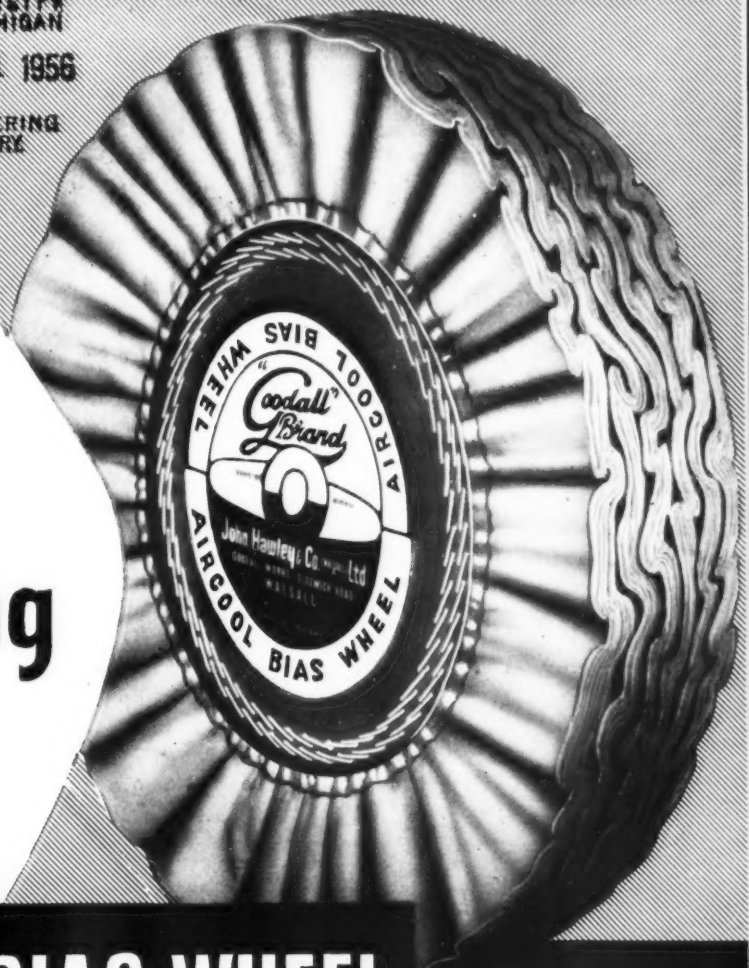

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THIS JOURNAL IS DEVOTED TO THE SCIENCE AND TECHNOLOGY OF PAINT APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING, GALVANIZING, ANODIZING, METAL SPRAYING AND ALL METAL FINISHING PROCESSES.

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CAVEAT EMPTOR

THE principle that thrusts upon the purchaser of a commodity or a service the full onus and responsibility for establishing a minimum standard of quality and satisfying himself that his purchase complies with that standard, may be a necessary one from the commercial point of view, but it is not one which always operates in the best interests of an industry.

The particular application of this thesis to the metal-finishing industry was stressed in a paper presented some while ago by a well-known personality in the electroplating industry at a meeting of the Purchasing Officers' Association. This paper cited several examples of instances where buyers had specified a particular finish without taking into account many factors which should have influenced their choice, and without informing the finishing contractor of the subsequent processing which the finished component was to be called upon to undergo.

A typical and very common example of this shortcoming is where a part is called for to be finished in nickel and chromium, when subsequent light-forming operations have to be performed on it. The use of a proprietary bright-nickel solution, now common practice in many plating shops, produces a coating much less ductile than is obtainable from the old Watt's type bath, and any attempt to form or bend a component so plated must result in rupture of the coating. If it is made clear at the time of placing the order that it is intended to perform such operations on the plated component the contractor can then select the appropriate plate for the purpose.

This is only one isolated, but not uncommonly encountered example of the necessity for purchasers to ensure that all factors influencing the service life of a finish are taken into account before laying down a specification.

This requirement can only be met in one of two ways. The purchaser or his agent must acquaint himself fully with all the technologies which relate to the processing of his product, or he must consult fully and freely with his contractors before placing his order.

Clearly the first of these expedients, desirable as it may be, is hardly capable of effective achievement, and although it is currently gaining increasing recognition that buyers and purchasing officers need to have some knowledge of the processes with which they are concerned, it is unreasonable to expect them to become expert.

This then throws into high relief the importance of sound relations of mutual consideration and confidence between purchaser and supplier. It is not always properly appreciated to what extent the welfare of an industry stems from just this factor.

All that has been said here applies in nearly every branch of industry, but there are reasons for believing that it applies with more than ordinary force throughout the metal-finishing industry. The part played by an attractive finish in promoting sales, and the loss of prestige resulting from finishes which fail prematurely in service have been stressed so often as to need no further comment here, but what perhaps is needed is a proper appreciation of how best the improvement of the performance of finishes can be brought about.

Most of the finishes available to industry today can give a good account of themselves if proper attention is paid to their application and their selection in terms of their expected service. *What the buyer has to beware is falling into the error of neglecting the significance of that protasis.*

Talking Points by "PLATELAYER"

TOPICAL COMMENT FROM THE MAIN LINES AND SIDE LINES OF METAL FINISHING

POWER POLITICS

THE recent increase of 18 per cent in the price of coal must soon be reflected in the price of electric current, which is becoming an ever more important factor in the overheads of electroplating operations. This item of cost has never been given much serious attention in the industry, and has tended to be looked upon as something fixed and inevitable, like the rent of the premises. The plating of a surface of 6 sq. ft. with a coating of nickel .001 in. thick consumes approximately one unit of electricity if a potential of 8 volts is used, assuming no losses. In actual practice the consumption of power is much higher in many plating establishments for a variety of reasons, and managements might usefully concern themselves with seeing how power costs can be reduced. In many instances substantial economies can be effected by simple measures.

The most important source of power loss is the resistance board, which should be rarely seen in an up-to-date plant. Yet in many places such boards waste power year in and year out, being employed more frequently as fixed resistances than as power regulating devices. Other common sources of waste are excessive bus-bar and cable runs of inadequate capacity, poor connections of all kinds, inefficient generating plant, and the use of solutions of low conductivity.

TREBLE CHANCE

ONE of the most commonly held views on nickel plating is that a break in the plating operation, even of an almost momentary duration, is liable to result in a laminated deposit and is therefore most sedulously to be guarded against. It therefore comes as something of a surprise to learn that one of the large American bumper manufacturers now applies no less than three different kinds of nickel successively, the total deposit being about .0015 in. thick. Following on the usual cleaning cycle the bumpers are anodically etched in sulphuric acid and then given a nickel "strike" from a Watts solution. After rinsing, the main thickness of nickel is applied from a semi-bright bath; a further rinse follows and then bright nickel plating is carried out directly over the second nickel deposit. A light polishing operation completes the nickel plating cycle prior to chromium.

The objects of the multiple process are to reduce porosity of the deposit, and the amount of polishing normally carried out after nickel plating in bumper production. A change in the type of bath and a break in deposition may well reduce the tendency for the continuation of pores through the nickel plate as its thickness increases. Bumper producers, in this country at any rate, do not favour bright nickel, because of the fact that these components are stressed in mounting and in service. Bright nickel does not seem to behave too well in service under such conditions unless the plating operation is kept under rigid control. A multiple deposit however, may enable bright nickel to be used for a final nickel layer, provided the production problems can be overcome, as they seem to have been in this case.

The likelihood that the failure of bright nickel deposits is due rather to stress cracks which may form under adverse plating or service conditions rather than to any greater inherent porosity of such deposits is confirmed by recent work on the direct determination of porosity by radiographic methods carried out in the United States. The method employed consisted in plating a deposit of radioactive iron under the nickel and determining the discontinuities in the latter by exposure to a photographic film. This direct and non-destructive method of assessing porosity and obtaining a permanent record, at the same time may, incidentally, have considerable possibilities in the future.

MORE FLUON

THE fact that the new I.C.I. plant for the manufacture of polytetrafluoroethylene (Fluon) is now reaching completion, and should be producing at the rate of 100 tons per annum at the beginning of next year, and double this amount later, is not without interest to metal finishers. Fluon is probably the most inert plastic material yet known, and this, coupled with its high temperature resistance, gives it outstanding advantages over similar materials in this field. Its use has, however, been limited because of its high cost, and it is hoped that the new plant will lead to a price reduction. It will then have considerable possibilities in the construction of many types of equipment.

Some Features of THE ANODIC TREATMENT of Semi-Finished Products in SINTERED ALUMINIUM

By J. HERENGUEL, P. LELONG and M. Le NOUAILLE*

THE sintering of powders of oxidized aluminium produces compact materials which have particularly good properties as regards to creep.(1) A recent paper gives an accurate statement of the relation between this characteristic and some factors such as the dimension of the original flakes, thickness of the oxide film surrounding them, importance of the deformation af er sintering and its conditions. In the course of deformation by rolling the evolution of the stratified two-phase texture which gives the material its specific properties has been most particularly studied. This evolution is clearly seen on " models " obtained by batch hot rolling of aluminium foils which have been previously anodized; it explains the variations in the creep resistance as a function of deformation. Some new technological problems appear with the use of sintered aluminium semi-finished products. In this paper the observations which have been made as regards to its anodic oxidation are related.

Two main observations can be made when such a material is submitted to anodic treatment:—

(*a*) When the other conditions remain identical, the current density is inferior to that of an aluminium sample of same purity but made by conventional methods.

(*b*) The oxidized sample exhibits a grey colour which can change to black for a film thickness of approx. 20μ.

It was assumed that the first phenomenon was due to the nature of the material itself: the oxide films contained in the metal are progressively included in the anodizing layer and act as " barriers " which hinder the progress of electrolysis. This mechanism has been proved and practical conditions of treatment established in parallel. Moreover, it has been proved that the grey or black colour of the sample was also due to the presence of oxide films in the second phase in the metal, acting as a mask.

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I.—Materials prepared for Investigations of Anodic Oxidation

Two types of sintered compacts have been made as in earlier experiments:—

1.—*Compacts* made from 99.5 per cent purity aluminium flake powder heat oxidized‡ before sintering, of various thicknesses and degrees of oxidation.

The powder was pressed at 550° C., extruded into 13-mm. dia. rods (ratio of reduction: $\frac{S}{s} = 25$)† or into bars 16-mm. thick (ratio of reduction: $\frac{S}{s} = 4$). One of these bars reduced to 14 mm. by scalping has been rolled down in several passes to a thickness of 0.5 mm. at 550° C., with sampling at 6, 4, 2, 1 and 0.5 mm. to study the influence of the reduction rate.

2.—A " *model* " obtained by batch hot rolling of 99.99 per cent purity aluminium foils 200 μ thick coated with anodic alumina films 4 μ thick before rolling.

Hot rolling was stopped at a pass giving the following degree of reduction:—

$$\frac{E - e}{e} \times 100 = 400 \text{ per cent}\dagger$$

The inner films which are in the form of flakes, are regularly dispersed as shown by the micrograph in Fig. 1.

II.—Anodizing Conditions of Sintered Aluminium Semi-Finished Products

The following results concern a compact made from flake powder 6 μ thick, heat oxidized to 0.2 μ and pressed at 550° C., extruded from 65 mm. dia. into bar 16 mm. thick, then hot rolled to 2 mm. The conditions of treatment are related to these

‡ " Heat oxidized " is used to describe oxidation as a result of heat, and " thermal oxide " the oxide so formed.

† S : section before extrusion—s : section after extrusion.
E : thickness before cold working.
e : thickness after cold working.

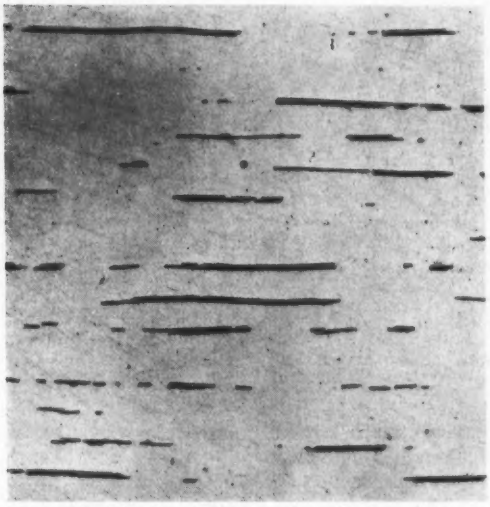


Fig. 1.—(*x* 100) *Longitudinal section of a "model" of a sintered compact made of anodized and batch hot rolled* (600° *C.*) *aluminium foils.* (*Original foils* 200 μ *thick coated with an anodic alumina film* 4 μ *thick on each face.*)

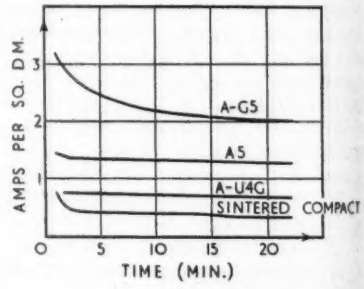
factors; when they are kept constant, the following typical aspects of the anodic treatment are observed:—

1.—For an equal voltage across terminals of the electrolysis tank, the current density obtained with the compact is inferior to that of a 99.5 per cent purity aluminium. The comparison is shown in Fig. 2: at 15 v. in 180 gm. per litre sulphuric acid and 20° C., the current density is 0.4 amp. per sq. dm. only, instead of 1.4 amp per sq. dm. in the case of 99.5 per cent purity aluminium and 0.7 amp per sq. dm. for the Al-Cu-Mg alloy (A-U4G),* under the same conditions. This fact is illustrated in another way by Fig. 3 which compares the voltages necessary for a given current density at the 15th min. of treatment, in the case of the compact, 99.5 per cent purity aluminium and industrial Al-Cu-Mg (A-U4G) and Al-Mg (A-G5)* alloys.

2.—At constant voltage, the current density is notably reduced in the course of electrolysis. This phenomenon is shown by Fig. 4 at two voltages *viz.* 15 and 45 v., for the compact previously defined. It can be seen that the phenomenon is the more marked the higher the voltage. *i.e.*, the current density (or the rate of anodizing) aimed at from the beginning is important. Inversely, to maintain a determined current density in the course of a treatment, it is necessary to increase the voltage, the higher the current density. For instance, to maintain a current density of 4.5 amp. per sq. dm. (180 gm. per litre H_2SO_4—20° C.) the voltage must be 24 v. at the beginning of anodic oxidation and 94 v. at the 30th min. In the case of 99.5 per cent purity aluminium the difference is less than 1 v.

As has been established for conventional metals and alloys,[3] it is necessary to define the range of temperature and current density which allow the formation of a hard, continuous and homogenous

* *A—U4G*: Al—4 per cent Cu—Mg; *A—G5*: Al—5 per cent Mg.



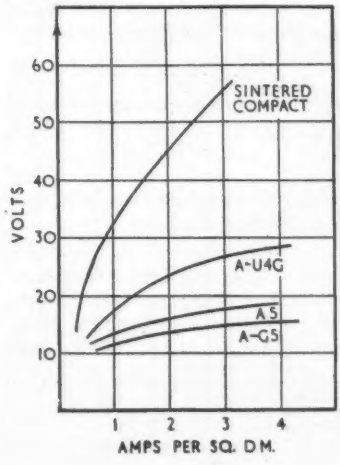
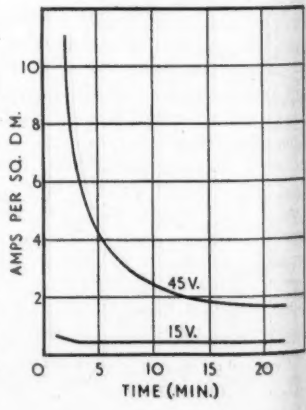


Fig. 2 (*above, right*).—*Comparison between current densities obtained, as a function of time, for various alloys and a sintered compact* (6 μ—*alumina* : 0.2 μ). (180 *gm./l.* H_2SO_4—20° C.—15 *v.*)

Fig. 3 (*left*).—*Voltages necessary to obtain a given current density at the 15th min. of anodizing for various alloys and the compact in Fig.* 2.

Fig. 4 (*below, right*).—*Variation of current density as a function of time at two voltages*: 15 *and* 45*v.* (*Sintered compact* : 6 μ—*alumina* : 0.2 μ.)



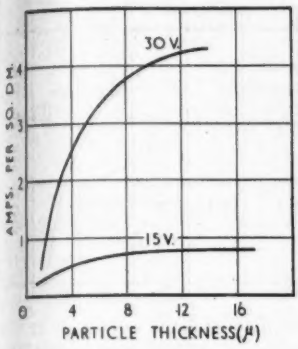
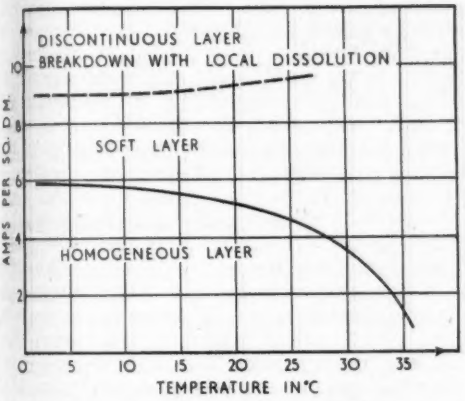


Fig. 5 (below, left).—Anodizing operating range of a wrought sintered compact (initial flake thickness : 6 μ —(thermal) oxide film : 0.2 μ) for a 30-min. anodizing time. (180 gm./l. H_2SO_4).

Fig. 6 (above, left).—Current density obtained at the 15th min. of anodic oxidation as a function of the original flake thickness, for various alloys (extruded from 60 to 13 mm.).



layer which when formed bears a direct relationship to the time of anodizing.

In the case of the compact, the practical operating range of anodic oxidation is not limited by the risk of a breakdown due to excessive current density but the main defect to be feared is the appearance of the soft surface layer which brings about limitations.

Fig. 5 illustrates the various ranges for a time of treatment of 30 min. in the case of the compact and electrolyte already mentioned. Above curve I important variations of thickness are observed which correspond to temporary breakdowns and dissolutions. Some parts of the specimens treated in such conditions undergo important size and shape variations. Above curve II the film has a superficial soft layer; beneath this curve the layer is hard and homogenous.

Two important features must be pointed out:—

(*a*) The electrolyte has been vigorously stirred during the tests.

(*b*) The voltages necessary to obtain, and chiefly maintain current densities after 30 min. are relatively high.

When the above conditions are fulfilled, it is possible to have thick and hard oxide films; for

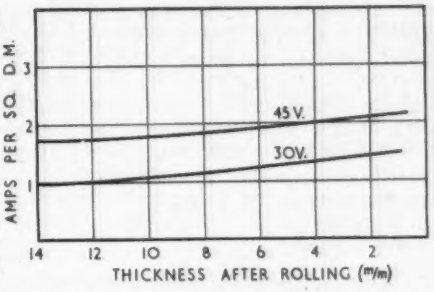


Fig. 7 (above, right).—Current density obtained at 30 and 45 v. after the 15th min. of anodizing (180 gm./l H_2SO_4 —20° C.) for a sintered compact (6 μ—oxide : 0.2 μ) extruded into bar and hot rolled from 14 to 0.5 mm.

instance after 30 min., 45 to 50 μ at 20° C. (voltage 24 to 94 v.). To obtain thicker films special electrolytes must be used.

Finally, for a correct operating range the output is the same as for aluminium and Al-Mg alloys of medium concentration (A1-1 per cent Mg, A1-3 per cent Mg) *viz.* 0.35 μ per amp. per sq. dm. per min.

III.—Influence of the Factors Relating to the Compact

The following factors have been considered as in the former studies of mechanical properties already mentioned:(2)

—size of the oxidized aluminium particles submitted to initial sintering;

—thickness of the oxide film on these particles before sintering;

—importance of deformation after sintering.

The *particle size* has a very strong influence. Fig. 6 shows the current density obtained after 15 min. at 15 and 30 v., with thicknesses ranging from 3.5 to 15 μ and the (thermal) oxide on these particles being everywhere 0.02 μ thick. All the samples were sintered by pressing at 550° C. and extruded from 60 to 13 mm. dia., the measurements being all taken on the cylindrical part of the bar. Again, it can be seen that the influence of this factor is the more marked the higher the rate of oxidation aimed at. It must be remembered that the current density of a 99.5 per cent purity aluminium at 15 v. is 1.4 amp. per sq. dm.

The (*thermal*) *oxide film* has also a very great influence: Table 1 indicates current densities obtained at 30 v. after 15 min. for two comparable compacts (original flakes: 6 and 8 μ thick), having an oxide thickness of either 0.02 μ or 0.2 μ, extruded into 13-mm. dia. rods.

It shows that the " barrier " effect of primary alumina films is very important.

The *influence of plastic deformation* is shown on Fig. 7. The current densities can be seen, at 30

and 45 v. after a 15-min. treatment for compacts, (flakes: 6 μ—(thermal) alumina: 0.2 μ) extruded into 16-mm. bars reduced to 14 mm. after scalping and rolled down to 0.5 mm. The variations are relatively small and can be easily explained by the structural changes which will be discussed later.

In addition, the stratified texture is revealed by variations of the rate of oxidation in a 1 : 2 ratio on an extruded bar between the surfaces parallel or perpendicular to the direction of extrusion, for high voltages.

IV.—Study of the Anodic Alumina Film

1.—*Origin of the Grey or Black Colour of the Film*

In the case of the compacts previously described the anodized surface is already grey where the film thickness reaches 2 to 3 μ and almost black for a thickness of 15 μ and over. When the film is detached by an electrolytic process it appears really grey and opaque; the underlying surface of metal is clear and without particular coloration.

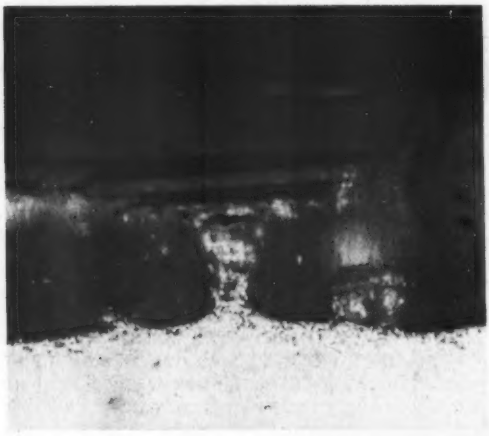


Fig. 8 (above).—(x750). Micrograph of the section of anodic film obtained on "model" showing the "mask" effect of alumina stratified during the progression of anodic oxidation.

TABLE I

Particles thickness ↓ / Oxide thickness →	0.02 μ	0.2 μ
6 μ	3.4	0.65
8 μ	3.80	1.20

The investigation carried out on the large-scale "model" allows the mechanism which leads to the grey colour to be seen. The anodic films obtained on the model are grey also. Micrographs of sections show the "mask" effect of the alumina layers in the metal which have been reduced to fragments by rolling. Fig. 8 illustrates this "mask" effect as anodic oxidation is proceeding: under the flakes, aluminium remains unaltered but during the progression of anodizing the lateral penetration of the electrolysis gives rise to a "stalk" of metal which is cut afterwards. In consequence of this, under each alumina fragment there is a certain amount of aluminium which is not connected to the anode and does not participate in electrolysis: it will remain in the film. In fact, the "mask" is permeable to electrolysis, at least to some extent, and the remaining metal does not form a homogenous mass but a series of small metallic parts. In addition, swelling during anodic oxidation can be seen clearly and the growth of the film on each side of the mask results in isolating the latter and gives rise to cavities which can be plainly seen on the micrographs.

All these metallic parts change the anodic film into a black body which absorbs light by multiple internal reflections, the high index of refraction of

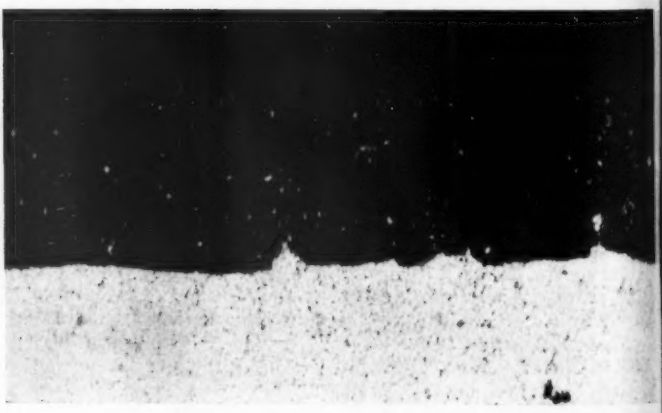


Fig. 9 (right).—(x800). Micrograph of a section of an alumina film on a sintered compact. In addition to some random large inclusions, the fine "dust" of the barely resolved particles can be seen.

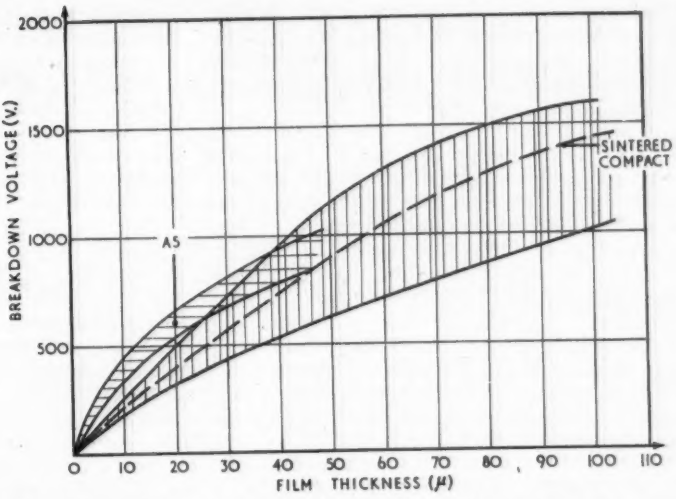


Fig. 10. — Breakdown voltages measured between the core of the sample and the external surface of the film as a function of its thickness, for ordinary aluminium and sintered compact.

aluminium also playing a part in this phenomenon. This is also the mechanism of the compact in which the "mask" consists of heat-oxidized alumina of the primary particles. This alumina is transparent or translucent and cannot cause the dark colour by itself. Metallic inclusions are observed in the micrographs of sections of the compact coated with its anodic alumina but the fragments of thermal oxide are not visible. These inclusions can be seen in Fig. 9 under a magnification of 800; they mainly form a "dust" of reflecting particles hardly resolved under the optical microscope and fairly uniformly distributed. A few larger random inclusions appear which correspond probably to masks wider or locally more numerous in the compact.

The actual presence of aluminium in the anodic film obtained on the compact made from 6μ flake powder (oxide: 0.2 μ) has been verified by chemical analysis. The detached film has been attacked by 10 per cent caustic soda at approx. 40° C. With an analytical sample weighing 1.454 gm. liberation of 23.3 cc. of hydrogen (brought back to normal conditions) has been obtained which means an aluminium content of 1.3 per cent in the film. On the other hand, 1 gm. of the film attacked by a modified Wiederholt's reagent(4) yields a dry residue weighing 63.7 mg. which corresponds to unattacked aluminium (A) and to thermal alumina (O) of the compact. Following this, the residue is treated by Tournaire's method(5) which allows thermal alumina to be separated ($O = 47$ mg.). Hence it follows that $A = 16.7$ mg. which corresponds to 1.7 per cent of the weight of the analytical sample, this being in fair agreement with the results of the first method. This analysis also allows the determination of the thermal alumina content of the compact to be made and its comparison with the values given by prior analyses. If M is the amount of aluminium metal transformed into anodic oxide S (supposed to be Al_2O_3):

$$M = 0.53\ S$$

on the other hand:

$$1{,}000 \text{ mg.} - (A + O) = S$$

and the thermal alumina content of the sintered compact is:

$$X \text{ per cent} = \frac{100 \times O}{M + (A + O)} = \frac{100 \times O}{0.53 + 0.47\ (A + O)} = 8.4 \text{ per cent}$$

This result and the 7 per cent previously determined in the oxidized original powder and in the compact itself show a rather good agreement. It has been calculated that 3 per cent of the weight of the aluminium in the sintered compact (which has given rise to the anodic layer) has not been affected by anodizing. In addition, this value is related to the factors which define the compact itself and deformations it has been submitted to.

Finally, an anodic film, detached and air heated at 750° C., will become white very quickly (within about 15 min.). At 650° C. it is difficult to whiten it wholly, even after heating for 2 weeks.

The grey coloration of the alumina films due to the presence of fine aluminium inclusions has already been observed by D. Altenpohl in the films obtained by oxidation in boiling water.(6)

2.—*Properties of the Anodic Film*

Breakdown voltage has been measured on a real sintered compact (powder: 6 μ—alumina: 0.2 μ) extruded into bar and hot rolled to 2 mm.

Anodizing has been carried out in 180 gm. per litre sulphuric acid at 20° C., with constant current density (2.5 amp. per sq. dm.) for times and voltages sufficient to obtain a film of required thickness. All the samples were sealed in hot water. Fig. 10 gives the curves of the maxima and minima found for breakdown voltage (measured between the core and the outer face of the film); the same curves drawn for a 99.5 per cent purity aluminium(7) should be compared with them. It can be seen that the sintered compact is very inferior in the case of thicknesses of low value but nearly equal for thick films. However, dispersion is still important.

The hardness of the films has not been measured with accuracy but it can be said that they are nearly as hard as conventional aluminium films when the treatment is carried out in the correct operating range previously defined.

Conclusions

The work described has aimed at defining the practical conditions for anodizing the semi-finished products made from sintered compacts of heat oxidized aluminium powder and the properties of the anodic film thus formed. The formation of a superficial anodic film gives the same advantage to these new materials with interesting heat-resistance characteristics as in the case of conventional materials: the use of the sintered materials at high temperature even leads to the formation of frictional films which can act as a " mask " on their surface.

The conditions of treatment have also been defined: the common electrolytes can be used but it is necessary then to have much higher voltages to maintain current densities yielding normal thicknesses for reasonable times of treatment. As in the case of conventional aluminium and aluminium alloys it is necessary to limit the temperature and current density with accuracy, to obtain the operating range which permits the formation of hard, dense and homogeneous films.

The authors are hoping to produce a range of semi-finished products made from oxidized aluminium sintered compacts the grades of which are defined by the properties of use (in this case the performances at high temperatures) and the facilities of manufacture or use *i.e.* their cost. This range of products is mainly defined by the size of the original particles and importance of deformation after sintering. These factors affect the anodic treatment also; the degree of thermal oxidation must be added to them as it appears to be of greater importance in this case than in the case of heat resistance. All these grades or " alloys " of a new type must be treated according to specific conditions, just as conventional alloys.

The oxide film is darkish grey and its opacity is probably due to the presence of fine metallic aluminium particles which have been revealed by micrography and analysis. These non-oxidized particles are included in the film due to the fragments of primary structural alumina acting as a " mask." The insulation property of the anodic film of the compact is not so good as that of conventional aluminium, especially in the case of low thicknesses. For a thickness greater than 50 μ it gives average values but dispersion is greater.

Anodic oxidation of the sintered and transformed metal can be considered as a very sensitive and significant method of study. In itself the structure of the material has a strong influence on the anodizing characteristics and aspect of the film, and inversely, these characteristics are specific of the structure, of its evolution and eventual defects.

Acknowledgements

This investigation has been carried out at the Centre de Recherches d'Antony and the authors thank the Society of the Tréfileries et Laminoirs du Havre and the Compagnie Française de Métaux for permission to publish this paper.

Thanks are due also to J. Boghen, Metallurgist of the Centre de Recherches who assumed the preparation of the sintered materials and greatly contributed to the investigation.

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LECTURES IN METAL FINISHING

Commencing on October 3, and subsequently on Monday evenings at 7 p.m., a series of lectures on "Research and Investigational Methods in Corrosion Science" is being staged at the Northampton Polytechnic, St. John Street, London, E.C.1.

This is in addition to the usual well established courses in electroplating and metal finishing which are once more being provided during the 1955/56 session. The courses are available either on a part-time day basis involving attendance for one-day and one evening per week, or alternatively as all evening classes.

The two principal courses are the Metal Finishing Operatives Course and the Metal Finishing Course, both of which prepare for the examinations conducted by the City and Guilds of London Institute in these subjects. Enrolment for these courses takes place between September 19 and 21.

COPPER PLATING FROM PYROPHOSPHATE BATHS

by T. A. DICKINSON

The use of copper-and brass-plating solutions based on pyrophosphates is a comparatively recent development evolved and patented in the U.S.A. by United Chromium Inc. This article gives some details of the process as operated in that country. The sole rights for marketing the process in the U.K. and certain Continental countries have been acquired by M. L. Alkan Ltd., Greenford, Middx.

WHILE they are not yet the most-used copper-plating solutions in the United States, pyrophosphate baths are currently gaining considerable popularity among American electroplaters because they are non-toxic and non-corrosive, relatively inexpensive to prepare and to use, and able to produce (with good speed) exceptionally smooth coatings which require little or no buffing.

Baths of the type in question are mildly alkaline, bivalent copper solutions made up and maintained with salts derived from pyrophosphoric acid ($H_4P_2O_7$). The salts include potassium pyrophosphate ($H_4P_2O_7$), sodium pyrophosphate ($Na_4P_2O_7$), copper pyrophosphate ($Cu_2P_2O_7$), and zinc pyrophosphate ($Zn_2P_2O_7$). Some of these salts are nearly insoluble in water, but will dissolve in an excess of potassium pyrophosphate—probably with the formation of complexes.

Typical pyrophosphate plating baths in current use have copper concentrations ranging from 3 to 4 oz. per gal. They are made by dispersing ingredients in water in the proportion shown in Table I.

TABLE I.*

Ingredients	3 oz./gal. Copper	4 oz./gal. Copper
Pyrophosphates	46 oz./gal.	62 oz./gal.
Potassium Hydroxide	2.4 oz./gal.	3.2 oz./gal.
Ammonium Hydroxide (29% NH_3)	1.2 fl.oz./gal.	1.2 fl.oz./gal.

The equipment required to use a solution of this type is notable mainly for its simplicity and low cost. It includes:

(1) A steel plating tank which may be lined with either rubber or ceramic coatings, but not with lead.

(2) Manually operated valves on steam and water lines or automatic instruments for controlling temperatures to $\pm 2°$ F. The temperature control coils may be of stainless steel or heavily nickel-plated steel. Outside heat exchangers are especially satisfactory where a continuous filtering set-up is employed, if they are of ample capacity and installed so that their source of heat will be automatically turned off when solution circulation is halted.

(3) An air-agitation spider, usually made from stainless steel or rubber-covered iron pipe. Its air supply is generally derived from a pressure blower *via* an air filter at the rate of 1 to 1½ cu.ft. per min. per sq.ft. of solution surface. (The approximate air pressure required is obtained by allowing 1 lb. per sq. in. for each 20 inches of solution depth to overcome solution head, plus 1 lb. per sq. in. to overcome pipe friction and supply agitation. For example, if the solution depth is 36 inches, the approximate pressure required is 1.8 plus 1 or 2.8 lb. per sq. in.).

(4) A filter suitable for removing fine particles. It may be made of stainless steel, rubber-lined steel, or cast iron—but not lead, copper, brass, or bronze. Its capacity should be sufficient to turn the solution over once in one to four hours.

(5) Any conventional 6-volt plating generator or rectifier which can produce cathode current densities up to 70 amp. per sq.ft.

(6) A tank rheostat, if the plating tank voltage is not controlled directly from the generator or rectifier. The rheostat should be equipped with an ammeter and a voltmeter, sufficient current capacity for the maximum tank load, and a voltage drop rating which will permit the regulation of voltage from 2 to 5 volts.

Prior to the preparation of a plating solution, the plating tank is filled with a weak solution of caustic potash (about ½ oz. per gal.) and heated to about 150° F. (65°C.) for 24 hours. Then the tank is cleaned by scrubbing and rinsing.

The plating bath may be mixed in one operation or as two or more batches—depending on the

*Figures quoted are for U.S. gallons throughout and should be increased by one-fifth to adjust to Imperial gallons.

TABLE II.

Theoretical times required to plate given thicknesses of copper from bivalent solutions at 100 per cent cathode efficiency.

Plate Thickness inches	Pounds Copper per sq. ft.	Ounces Copper per sq. ft.	Amp.-Min. per sq. ft.	PLATING TIME IN MINUTES										
				At 10 Amp. per sq.ft.	At 15 Amp. per sq.ft.	At 20 Amp. per sq.ft.	At 25 Amp. per sq.ft.	At 30 Amp. per sq.ft.	At 40 Amp. per sq.ft.	At 50 Amp. per sq.ft.	At 60 Amp. per sq.ft.	At 70 Amp. per sq.ft.	At 80 Amp. per sq.ft.	At 100 Amp. per sq.ft.
.0001	.0047	.075	106	10.6	7.1	5.3	4.2	3.5	2.6	2.1	1.8	1.5	1.3	1.1
.0002	.0094	.150	212	21	14	10.6	8.4	7.1	5.3	4.2	3.5	3.0	2.6	2.1
.00025	.0117	.188	265	27	18	14	10.6	8.8	6.7	5.3	4.5	3.9	3.4	2.7
.0003	.014	.225	318	32	21	16	13	10.6	8.0	6.4	5.3	4.5	4.0	3.2
.0004	.019	.300	424	42	28	21	17	14	10.6	8.5	7.1	6.1	5.3	4.2
.0005	.023	.375	530	53	35	27	21	18	13	10.6	8.8	7.6	6.7	5.3
.0006	.028	.45	640	64	42	32	25	21	16	13	10.6	9.1	8.0	6.4
.0007	.033	.52	740	74	50	37	30	25	18	15	12	10.6	9.3	7.4
.00075	.035	.56	800	80	53	40	32	27	20	16	13	11	10.0	8.0
.0008	.038	.60	850	85	57	42	34	28	21	17	14	12	10.6	8.5
.0009	.041	.67	950	95	64	48	38	32	24	19	16	14	12	9.5
.001	.046	.75	1060	106	71	53	42	35	26	21	18	15	13	10.6
.00125	.057	.93	1330	133	89	67	54	44	33	27	22	19	17	13
.0015	.070	1.13	1590	159	106	80	64	53	40	32	26	23	20	16
.00175	.082	1.31	1860	186	124	93	74	62	46	37	31	27	23	19
.002	.094	1.50	2120	212	142	106	84	71	53	42	35	30	26	21

amount of solution required and the capacity of any given mixing tank.

If necessary, the plating tank may be used as a mixing tank. However, since undissolved chemicals may produce rough deposits if mixing is done in a plating tank, most American platers prefer separate mixing tanks. The latter make it possible to filter solutions before they reach the plating tanks.

After it is thoroughly cleaned, the mixing tank is half filled with water which is heated to about 120°F. (50°C.). Then potassium hydroxide is added, and the water is either manually or mechanically agitated until it is completely dissolved.

Next, pyrophosphates are added to the solution and mixing action is continued until they are apparently dissolved. Then, if a separate mixing tank has been used, the solution is filtered into the plating tank.

Ammonium hydroxide is added to the solution in the plating tank, after which a small quantity of potassium hydroxide may be used to adjust the *p*H of the bath to a value of 8.5 (the allowable deviation in *p*H during production ranges from 8.2 to 8.8).

The solution can be used as soon as electrolytic copper anodes are installed in the plating tank. Clean, scale-free anodes are required and they must extend to about the same depth as that of the parts to be plated. An anode is usually considered to have sufficient area if it has 2 to 4 in. of width per foot of rod.

During plating operations, bath temperatures of 110° to 140° F. (45° to 60° C.) are maintained (the higher temperatures being preferred where maximum current densities are required; the lower temperatures, where deposits of optimum brightness are desired). Heat exchangers, if used, are adjusted so that the flow of return solution will not exceed 150° F. (65° C.).

Good deposits have been claimed with cathode current densities ranging from 10 to 70 amp. per sq. ft., anode current densities of 20 to 100 amp. per sq. ft., and 2 to 5 tank volts — depending on the operating temperature, the degree of agitation, the size and shape of the article to be plated, and the surface condition of the metal in each circumstance. Table II indicates approximate theoretical plating speeds.

Baths are considered to be in good operating condition as long as routine chemical analyses show that their constituents are within the ranges shown in Table III.

The ratio of pyrophosphate to copper is especially important and should be maintained between 6.8 to 1 and 7.2 to 1. However, in plating zinc castings, higher ratios (up to 7.5 to 1) are often necessary.

Ammonia lost by volatilization is generally replenished by adding about 13 gm of ammonium hydroxide per sq. ft. of solution per 8-hour day, but in large plants this procedure is sometimes varied by introducing ammonia gas from a cylinder into the air line leading from the blower to the air-agitation spider.

TABLE III.

Optimum range of constituent content.

Ingredient	Oz. per Gal.	gm. per l.
Copper	2.5 to 4.0	18.5 to 30
Pyrophosphate	17.5 to 28	130 to 210
Ammonium Hydroxide	0.20 to 0.40	1.5 to 3.0

Pyrophosphate plating is carried out in orthodox equipment as can be seen from this illustration which shows a copper-plated steel part being removed from a copper pyrophosphate plating bath.

Occasional analyses are also made for orthophosphate, which has no bearing on the plating characteristics of the bath until a fairly large quantity is present. Factors which tend to cause orthophosphate build-up include a low *p*H, a high ratio of pyrophosphate and excessive plating temperatures.

Orthophosphate in a new solution amounts to about 1.0 oz. per gal. It should not be allowed to exceed 15 oz. per gal. in any solution.

Pyrophosphate planting baths are not sensitive to most of the impurities commonly encountered by electroplaters. However, such impurities as lead, cyanide, and oil will affect their current density range and cause them to produce dull or streaky deposits.

In general, lead contamination can be avoided by not using lead coils, linings, filters, or fittings; oil contamination can be corrected by occasionally filtering a solution through activated carbon; and cyanide contamination can be prevented by using strike solutions which contain no cyanide.

Where a cyanide strike is used, contamination can be minimized by thoroughly rinsing parts just before they are plated; and cyanide contamination can be corrected, when and if necessary, by slowly stirring about $\frac{1}{8}$ gal. of hydrogen peroxide (100 volume, 30 per cent by weight H_2O_2) into each 100 gallons of pyrophosphate plating solution. Where the latter procedure is employed, the bath can generally be used after it is allowed to stand for about 15 minutes.

A typical cycle specified for the copper plating of steel and cast iron in pyrophosphate baths calls for:

(1) Solvent or vapor degreasing, alkali soaking, or alkali power spray washing of parts to remove heavy greases, oil films, or caked buffing compounds.
(2) Electrolytic alkali cleaning of parts in a heavy-duty bath at six volts for 30 seconds to four minutes at a temperature of about 200° F. (95° C.).
(3) Rinsing of parts in water heated to about 130° F., (55° C.), and then in cold water.
(4) Acid dipping parts for 5 to 10 seconds in 10 to 50 per cent (by volume) concentrated hydrochloric acid; or in 5 to 10 per cent (by volume) concentrated (66° Beaumé) sulphuric acid.
(5) Rinsing of parts in cold water.
(6) Plating of parts in a copper strike solution (comprising 2 oz. per gal. copper, 1 to 2 oz. per gal. free cyanide, and $\frac{1}{2}$ to 1 oz. per gal. caustic soda) for about $\frac{1}{2}$ to 3 minutes or until they are completely covered.
(7) Rinsing of parts in cold water and a 5 per cent (by volume) solution of sulphuric acid (66° Beaumé).
(8) Rinsing of parts in water heated to 130° F. (55° C.).
(9) Plating of parts in pyrophosphate bath, as heretofore indicated.
(10) Rinsing parts in cold, then hot, water.
(11) Drying parts.

Where nickel is to be plated over unbuffed copper, no drying operation is necessary, Parts are simply acid-dipped, rinsed, and transferred directly to a nickel-plating tank.

Except for the usual variations in cleaning and acid dipping requirements, the cycles employed in plating non-ferrous materials differ from the ferrous plating cycle only to the extent that except in the case of zinc alloys the use of a copper strike solution is optional.

Protection of Magnesium Alloys

Discussion at Meeting held to Celebrate Coming-of-Age of Magnesium Elektron Ltd.

THIS year marks the twenty-first anniversary of the formation of Magnesium Elektron Ltd. as a company, and to celebrate the occasion a two-day meeting of representatives of all the company's licensees was held in Manchester on June 16 and 17. This meeting was attended by forty-seven representatives of twenty-five companies in nine countries, and as the first occasion of its kind it can be regarded as a milestone in the history of the metal in this country.

The two-day programme included tours of the company's works at Clifton Junction, and the reading of four papers. A comprehensive range of exhibits of magnesium components, principally in magnesium zirconium alloys, was on show and the proceedings culminated in a dinner.

Among the papers presented at the meeting was one by Dr. W. F. Higgins, senior metallurgist of the company, who spoke on "Modern Concepts in the Protection of Magnesium Alloys." In the course of his remarks Dr. Higgins referred to the widespread use of the chromate ion as the basis of surface passivating treatments, although the films produced in such baths are, in general, too thin to offer much resistance to physical damage. As a consequence, there has been a tendency to seek a treatment which gives thicker and harder films even if this means sacrificing the inhibiting properties of the chromium compound. No success has attended efforts to form thicker and harder films merely by chemical means, and the heavier films now being produced are the result of interaction with nascent ions produced in electrolytic baths. Under such conditions, it does not seem possible to include the chromate ion in the form in which it is required for passivation. Since, however, the films are porous to some degree or at least capable of absorbing liquids, there seems no reason why soluble chromates should not be absorbed into such films as a subsequent step. It is indeed usual to seal the films either with organic materials, waxes, lacquers and the like, in order to prevent ingress of all aqueous corrodants, and an inhibitor pre-absorbed into the film would seem an obvious step to take. Among treatments depending for this effect on electrolysis of various solutions which have recently been announced in the U.S.A. are the "H.A.E." process emanating from Frankfort Arsenal, the "No. 17" process developed by the Dow Chemical Co. and the still more recent "CR-22," also from Frankfort Arsenal. Both the latter yield films which are green in colour, probably indicating the presence of chromium compounds (which are certainly present in the Dow bath), but in a form in which they are probably not capable of exerting a passivating action. The H.A.E. process when carried out to completion yields a dark brown or chocolate colour, but modifications, which are essentially short-period treatments, give lighter coloured and, incidentally, thinner films. The full H.A.E. film is extremely hard, but it is brittle and spalls badly under shock. It also has a considerable adverse effect on the fatigue resistance of the metal. How far any of these treatments are necessary depends entirely on the environment in which the component is to be used.

Dealing with the problems attendant upon the production of a satisfactory paint film on magnesium Dr. Higgins mentioned that the surface of magnesium castings was generally unsuitable for the retention of a sound paint film because of the presence of numerous minute flaws, and also because the corrosion products of magnesium, being alkaline in nature, could have a deleterious effect on some paints.

The M.E.L. Fluoride Anodizing Process.

A method which had been developed by the company (the subject of British Patent No. 721445, and patents pending abroad), for the production of a refined surface on a casting, was fluoride anodizing. This process involves anodizing the magnesium in a solution of ammonium bifluoride so that all cathodic metals initially present or picked up during factory operations are removed as soluble compound. Foundry sand, oxide skins and flux inclusions, if present, as well as iron contamination from shot blasting or machining, are also removed with the result that the surface of the casting is left free of all corrosion-promoting contaminants and coated with a thin adherent film of magnesium fluoride. This may be left *in situ* and will serve as an adequate foundation for a subsequent sealing operation, or it may be removed quite simply and a chromate film produced in the usual way.

Operation of the Process.

Before treating articles by the fluoride anodizing process any loosely held sand should be removed by brushing, and thick layers of grease or paint, if

Some Notes on the Effect of the Presence of IRON SALTS in Hot-Dip GALVANIZING

by H. BABLIK, F. GÖTZL, and E. NELL

It is a known fact that iron salts on the surface of goods to be galvanized lead to an increased production of dross according to the reaction:

$$FeCl_2+Zn=ZnCl_2+Fe$$
$$Fe+xZn=FeZn_x \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

A part of these small iron-zinc crystals which have formed in the immediate vicinity of the surface of the dipped article will be retained in the adherent pure-zinc layer, increasing its viscosity and thus its thickness in a quite irregular way. The remainder of the crystals gets dispersed in the bath and will in time settle to the bottom, causing no damage other than augmenting the amount of dross. Neither effect is desirable. In addition, the fluxing medium will lose part of its efficiency, when employed in keeping in solution, the iron salts, which are mostly of a slightly alkaline composition. Therefore it is highly desirable to get rid of the iron salts which have been formed on the surface during pickling, prior to dipping the goods into the zinc bath.

A very interesting, and hitherto unpublicised effect, which is of prime importance in practical galvanizing, is produced by the iron salts on the surface of goods which are to be galvanized in baths that contain aluminium. Galvanizing in Al-containing baths is necessary when good ductility of the coating is desired. Only coatings with a maximum thickness of 100-150 gm per sq. metre have been found to be satisfactory in this way. Iron sheets are obviously the material principally subjected to this particular process of galvanizing. In order to join them to one another or to shape articles out of them, they have to be bent over small radii without causing damage to the coating or causing it to flake off. This is achieved by alloying the zinc bath with a small amount of Al, the exact amount depending on the properties of the sheet iron, falling between 0.08 and 0.20 per cent Al.

Some time ago the authors were able to show that with such an aluminium content in the zinc bath there is no formation of an iron-zinc alloy layer, during the usual dipping periods. The reaction of the iron with the zinc is inhibited for some time because the iron reacts preferably with the aluminium of the bath, creating a very thin layer of Fe-Al phases, which obstruct the diffusion of iron and zinc so that either no, or only a very rudimentary, alloy layer of iron-zinc phases can be formed.

But when iron salts are present on the surface of the iron sheet, the above-mentioned process is greatly influenced and modified. It is known that in aqueous solutions the less noble metal in the order of the electrode potentials precipitates the nobler metal from its solution. The same holds true, if the electrolyte is a molten salt, as we pointed out some time ago. The order of the normal electrode potentials of the metals in question is:

Al 1.7 volts
Zn 0.76 volts
Fe 0.44 volts

Therefore in the absence of Fe-salts in the flux or on the surface of the iron the following reaction will take place:

$$3\,ZnCl_2+2\,Al=2\,AlCl_3+3\,Zn \quad \ldots\ldots\ldots\ldots(2)$$

But with iron salts in the flux the iron reacts preferably with the aluminium in the bath:

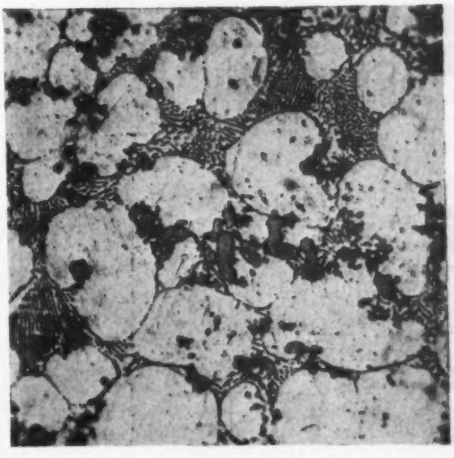
$$3\,FeCl_2+2\,Al=2\,AlCl_3+3Fe \quad \ldots\ldots\ldots\ldots(3)$$

followed by:

$$3\,Fe+9\,Al=3\,FeAl_3 \quad \ldots\ldots\ldots\ldots(4)$$

The reaction according to eq. (2) is a relatively

Fig. 1.—Blue crystals of $FeAl_3$ as reaction product: $3\,FeCl_2 + 11\,Al = 2\,AlCl_3 + 3\,FeAl_3$ x 350



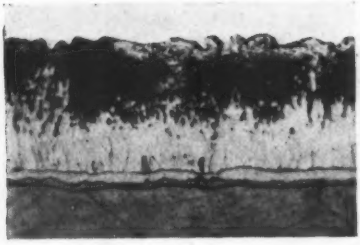


Fig. 2.—(Top left) Microsection of a zinc coating. Flux: $FeCl_2$ or $ZnCl_2$. Zinc bath not alloyed. x 1200

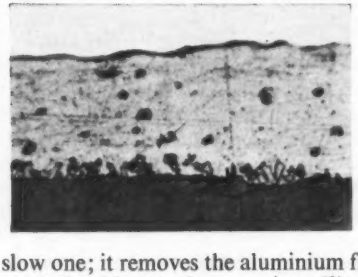


Fig. 3.—(Bottom left) Microsection in an Al alloyed bath. Surface free of iron salts. Flux: iron-free $ZnCl_2$. x 1200

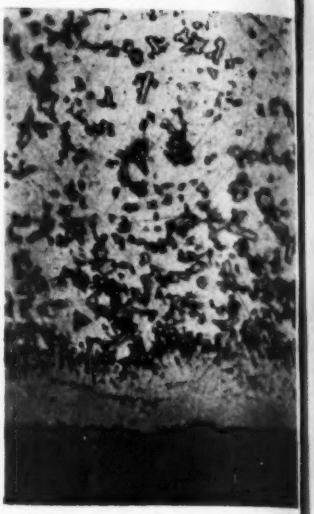


Fig. 4.—(Right) Microsection of a zinc coating in an alloyed bath. Flux: $FeCl_2$. Surface coveyed with iron salts. x 1200

slow one; it removes the aluminium from the bath at a tolerable rate, but reactions (3) and (4) occur much more vigorously and, in addition, they remove comparatively much more aluminium from the solution, rendering it inactive.

The validity of eqs. (3) and (4) has been demonstrated by the following experiment. A certain amount of $FeCl_2$ was placed on molten Zn containing about 2 per cent Al. After 5 minutes at about 453°C the melt was cooled and the metal was sectioned. It showed, as can be seen in Fig. 1, the formation of an ample amount of $FeA1^3$ crystals (called blue crystals, after the blue tinge they show in ocular observation).

It is obvious that the same reaction occurs in practical galvanizing, if iron salts on the surface of the sheets get into contact with zinc containing aluminium. By the above reactions the zinc bath loses so much of its aluminium content in the immediate vicinity of the ingoing sheet that the reaction between iron and zinc takes place as if very little or no aluminium were present; as, indeed, locally is the case. This point is illustrated in Figs. 2-4. Galvanizing in an A1-free bath gave the same structure of the coating whether $ZnC1_2$ or $FeC1_2$ was used as a fluxing material. (Fig. 2). But if aluminium was present in the bath then there was a great difference in the structure of the coating, depending on whether $FeC1_2$ or $ZnC1_2$ was the flux. A surface from which the iron salts were carefully removed and using pure $ZnC1_2$ as a flux, gave a structure as shown in Fig. 3. Here the absence of any alloy layer can be remarked, as the aluminium is able to enforce its full inhibiting action. In contrast to that, Fig. 4 shows the formation of a thick alloy layer on a sample on which $FeC1_2$ had been the fluxing material. In this case the aluminium content of the bath has been locally so much diminished that no inhibiting effect has been exerted and consequently a structure of the coating results that is almost the same as in a bath containing no aluminium at all.

This emphatically demonstrates the prime importance of removing all iron salts from the surface of the iron and from the flux, when galvanizing in a bath containing aluminium in order to avoid the formation of an alloy layer.

Protection of Magnesium Alloys

(*Continued from page* 346)

present, should be removed either by vapour degreasing or caustic-soda treatment. The work pieces are fixed in pairs in good electrical contact on electrode bars across a suitable insulated tank and suspended not less than nine inches below the surface of a ten per cent solution of ammonium bifluoride in water. The work should be arranged so that approximately equal surface areas are present at each electrode. All parts of the fixing clamps below the surface of the liquid must be of magnesium rich alloy. Alternating current is applied and the voltage increased progressively until 90-120 volts is reached. Current flow is usually heavy at first but diminishes rapidly as impurities are removed and a coating of unbroken magnesium fluoride formed in their place. When this occurs the process may be regarded as complete. The treatment is usually continued for 10 to 15 minutes or until the current falls to less than 5 amp. per sq. ft. of surface. The current is then switched off and the work pieces washed, preferably in hot water, and quickly dried.

DEGREASING
of Metal Components with Trichlorethylene
Some Notes on Solvent and Vapour Processes

by A. G. GARDNER, A.I.M.

Introduction

THE removal of dirt, grease and oil is a necessary process in nearly every factory and workshop in which metal plays any part and is an essential preliminary to any kind of finishing treatment. With regard to the latter aspect the chief occasions when dirt, grease and oil have to be removed, may be summarized as follows:—

After: cold rolling, drawing, stamping, pressing, machining, grinding, tinning and polishing.

Before: pickling, sandblasting, rust-proofing, galvanizing, tinning, soldering, electroplating, anodizing, gilding, enamelling, lacquering and japanning.

The degree of cleanliness required and the method of cleaning will vary with the application. There are three general methods for degreasing metals, namely:

(*a*) Solvent degreasing.
(*b*) Alkali degreasing.
(*c*) Emulsion degreasing.

The present article is concerned with the first of these methods, namely solvent degreasing and in particular with the use of trichlorethylene. Before considering this latter solvent in some detail, it would be of some interest to mention its relationship to other chlorinated hydrocarbon solvents.

The Chlorinated Hydrocarbon Solvents

The chlorinated hydrocarbon solvents were developed mainly because of their non-inflammability and non-explosive characteristics. In addition they possess increased solvent-power towards all types of oil and greases, by comparison with the corresponding straight hydrocarbon types and display better heat characteristics. The four most commonly encountered chlorinated hydrocarbon solvents are carbon tetrachloride, trichlorethylene, perchlorethylene (also known as tetrachloroethane) and ethylene dichloride.

Carbon tetrachloride is the most toxic and in the presence of moisture and iron oxide it undergoes some chemical decomposition giving rise to corrosion problems. Research is being carried out to find suitable chemical stabilizers for carbon tetrachloride. In addition to the above disadvantages its low boiling point and light, easily diffused vapours are not suitable for vapour degreasing.

Ethylene dichloride finds wide industrial use as a general solvent but its use in vapour degreasing is diminishing because it is classed as a moderately inflammable solvent.

Stabilized trichlorethylene and perchlorethylene are the two solvents most suitable for degreasing. Both solvents are non-inflammable. The principal physical properties of these two solvents are given in Table I.

The main difference between trichlorethylene and perchlorethylene for use as degreasers lies in their respective boiling points shown in the Table. Vapour degreasing plant employing trichlorethylene may be indirectly heated with gas or low pressure steam. The latter method results in there being no danger of overheating the oil-solvent mixture or engendering thermal breakdown of solvent which can take place if solvent vapours come into direct contact with a flame. The lower boiling point of trichlorethylene also simplifies the removal and handling of degreased material.

Trichlorethylene in the pure state is relatively stable but when heated above 125° C. and especially in the presence of traces of moisture, which in practice it is almost impossible to eliminate, the pure solvent decomposes forming small amounts of free hydrochloric acid which may corrode both articles being degreased and the containing equipment. In consequence commercial trichlorethylene for degreasing is stabilized, usually with organic amines which both retard decomposition and also neutralize any hydrochloric acid liberated. Nevertheless, suitable precautions should be taken to reduce decomposition to a minimum and these include avoidance of overheating and keeping the apparatus closed, especially in humid weather when the moisture of the air can condense on the inner cooled walls of the chamber. Wet work should not normally be hung in the trichlorethylene degreaser to dry, but if this is found absolutely necessary, a water separator should be fitted.

Since perchlorethylene vaporizes at a temperature well above the boiling point of water, acid

TABLE I.
Physical Properties of Trichlorethylene and Perchlorethylene.

	Trichlorethylene	Perchlorethylene
Chemical Formula	$CHCl : CCl_2$	$CCl_2 : CCl_2$
Molecular Weight	131.4	165.8
Boiling Point at 760 mm.	86.7° C.	120.8° C.
Latent Heat of Vaporization. (B.T.U. per lb.) ...	103.1	90.1
Vapour Density	4.53	5.72
Specific Heat at 20° C.	0.223	0.216
Solubility of Water in Solvent, %	0.03	0.02
Pounds per gallon (15° C.)	12.3	13.5

attack due to hydrolysis is a negligible factor. The higher boiling point of perchlorethylene permits better solution of certain greases and waxes, but its use is not common in this country.

Trichlorethylene

Solvent degreasing in the form of trichlorethylene is probably unequalled for the removal of all types of oil and grease whatever the quantity. It is of course appreciated that work intended for electroplating must be treated by an alkali process to ensure a chemically-clean surface as opposed to the grease-free, physically-clean surface achieved by trichlorethylene degreasing. Even so, it is common practice in the electroplating industry to degrease work in trichlorethylene before chemical cleaning and plating. This is particularly the case where heavy grease contamination is present which would quickly exhaust an alkali bath.

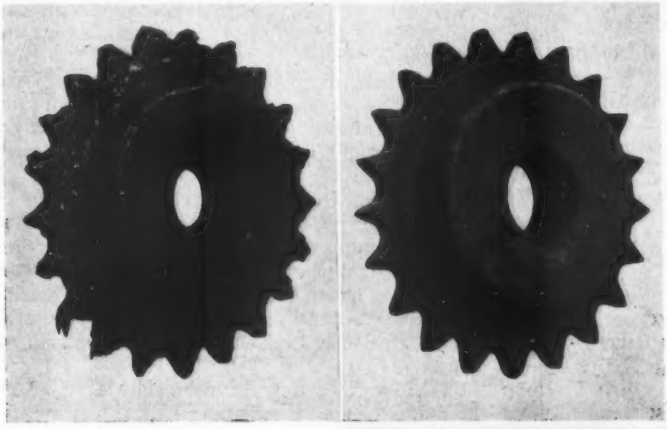


Fig. 1a. (*above left*). *Chain sprocket coated in heavy grease before trichlorethylene treatment.*
[*Courtesy of I.C.I. Ltd.*

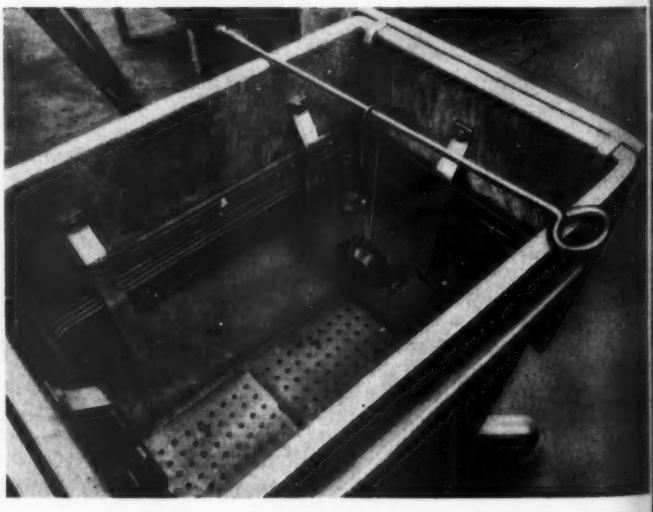


Fig. 1b. (*right*).—*The chain sprocket suspended in the vapour rising from boiling trichlorethylene in a degreasing plant.*
[*Courtesy of I.C.I. Ltd.*

Fig. 1c. (*above right*).—*Appearance of sprocket after degreasing treatment in trichlorethylene plant.*
[*Courtesy of I.C.I. Ltd*

The chief advantages of trichlorethylene may be stated as follows:—

(1) Ability to remove quickly thick deposits of oil or grease.
(2) No deterioration in cleanliness with increased through put of work since the equipment is arranged to give each load a rinse in pure distilled solvent.
(3) Work is left in a dry neutral condition.
(4) No attack on the metal, however long the exposure to trichlorethylene.

Trichlorethylene is a heavy, colourless, volatile liquid. It can be heated up and boiled with a small input of heat, *e.g.*, the heat required to convert 1 lb. of water into steam will vaporize 8½ lbs. of trichlorethylene. It has excellent wetting properties and gives rapid penetration. Trichlorethylene is non-inflammable. It does not attack the common metals although in certain circumstances it may be affected by fine particles of aluminium and magnesium, which are highly reactive. Simple operating and maintenance measures avoid trouble however. Iron and steel surfaces are so thoroughly cleaned in contact with the solvent or its vapour that they are liable to rust on exposure to air. For this reason it is advisable to galvanize such metals when they are used in the construction of plant using trichlorethylene.

The essential simplicity of the process can be appreciated from the series of photographs of Fig. 1. A chain sprocket coated in heavy grease is suspended in the vapour rising from boiling trichlorethylene in a degreasing plant. Solvent immediately condenses on the cold metal surfaces, dissolves the grease and runs back into the plant. Within a short time the sprocket has reached the vapour temperature and condensation ceases. Degreasing is complete, and the sprocket is withdrawn from the plant in a perfectly clean condition.

Trichlorethylene is used principally in the form of vapour and liquor-vapour processes and these will now be briefly described.

Vapour Degreasing.

The trichlorethylene is heated to boiling by electricity, steam or gas. Round the top of the tank are cooling coils to condense the hot vapour and prevent its escape. Work to be cleaned is hung in the hot vapour, which condenses on the work and dissolves oil and grease as it runs back into the sump. The oils removed are only slightly volatile so that the vapour condensing is essentially that of the pure solvent. The solvent can be recovered from the grease and oil that accumulate in the sump by distillation, either in the plant itself or in a suitable still kept specially for the purpose. An illustration of a typical gas-heated plant is given in Fig. 2.

The volume of solvent condensing and consequently the effectiveness of cleaning, is governed by the weight of metal, its specific heat, the latent heat of condensation of the solvent and the temperature rise necessary to bring the work to the temperature of the solvent vapour. Light metal sections covered with heavy films of oil will clean poorly, while heavy metal sections in the same condition are more effectively cleaned. A vapour degreasing plant does not completely remove solid dirt from the surface, although this, together with the difficulty mentioned in connexion

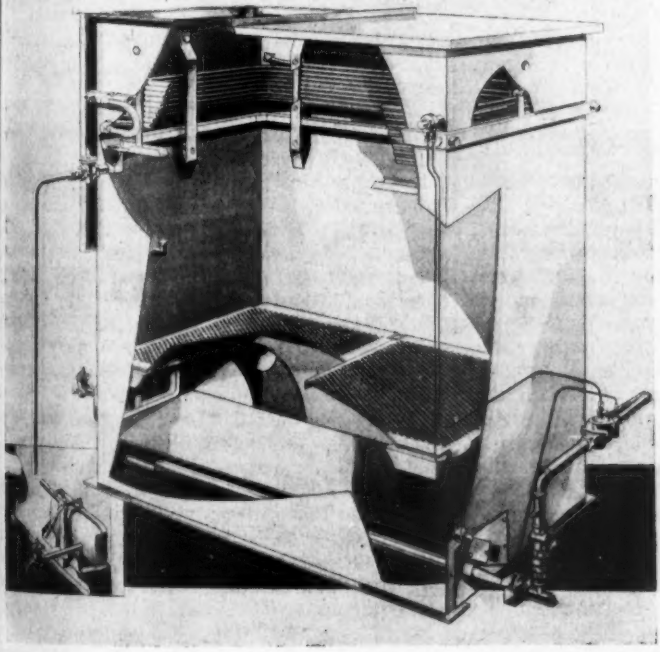


Fig. 2.—Gas-heated vapour degreasing plant.
[Courtesy of I.C.I. Ltd.

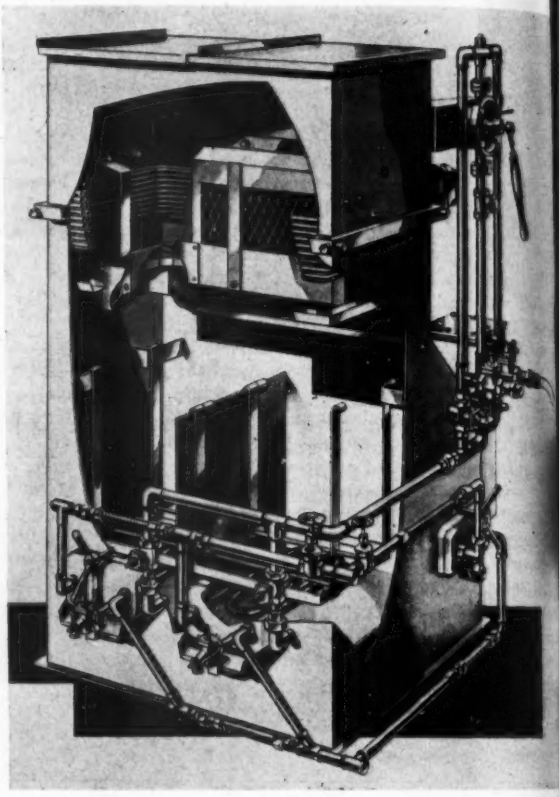


Fig. 3.—Two-stage, steam heated multi-liquor plant. [Courtesy of I.C.I. Ltd.

with light metal sections, may be overcome by spraying the work with jets of hot solvent or treatment, successively, in boiling solvent and solvent vapour. Very often treatment in a boiling liquid alone suffices to remove solid dirt.

Vapour degreasing plants should have sufficient heat input to keep the vapour level high enough in the chamber for the work to be completely immersed in vapour. The condensing facilities in the form of cooling coils in the upper part of the chamber should be adequate to prevent loss of solvent. Equipment should be chosen in relation to the size and volume of the work to be degreased. The plant must have sufficient capacity to allow each load to be warmed up to vapour temperature and then removed slowly, but on the other hand it should not have so much excess capacity that it has to be kept "idling" during a substantial part of the day, as this increases costs of both fuel and solvent in relation to the volume of work handled.

Liquor degreasing

This process involves the immersion of the work in liquid trichlorethylene. The flow of liquid past the work means that solid particles of dirt are more readily removed than in vapour degreasing. The equipment consists of a tank, the lower half of which may have one, two, or more compartments containing boiling trichlorethylene. A bank of condensing coils at the top prevents the escape of solvent vapour and the condensate is returned to the last compartment. An article to be degreased is immersed in the various compartments in succession, receiving its final washing in clean solvent condensate in the last compartment. The plant is so arranged that there is a displacement of solvent by the returning condensate from compartment to compartment in the opposite direction to that of the work passing through the plant. A self-cleaning action is thereby obtained, and the grease and oil gradually accumulate in a special concentration compartment or a speci still. A two-stage multi-liquor plant, stea heated, is shown in Fig. 3.

It is possible to combine washing in boilin solvent with degreasing in vapour and suitabl equipment is available for this purpose, a illustrated in Fig. 4. The liquor-vapour plant i similar in construction to the vapour plant but i divided into two compartments each fitted wit heating facilities as will be seen in the illustration. In use, one compartment is kept full of boilin solvent and the other acts as an ordinary vapou plant. Clean distillate is returned to the botto of the liquor compartment, displacing dirty liquo over the weir into the sump of the vapour com partment, thus maintaining a self-cleaning action. The work is first dipped in the boiling liquor where solid matter such as polishing compounds, swarf and dirt is removed by the ebullient action; a final dip in vapour completes the cleaning action. The liquor-vapour process is very popular in the plating trade, but is generally used wherever light-weight articles are to be degreased. The reason for this has already been explained in the section on vapour degreasing.

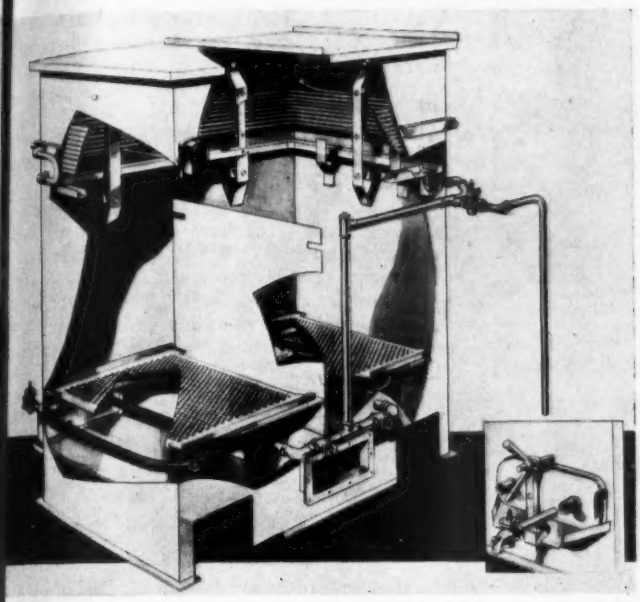


Fig. 4.—Liquor-vapour degreasing plant.
[*Courtesy of I.C.I. Ltd.*

much better to treat such work first in liquor and finally in vapour, and a liquor-vapour plant is most suitable.

(3) When a number of flat articles held together by oil or grease have to be cleaned, vapour degreasing can only be employed if the articles are first separated in racks; basket-loads of such parts all stuck together should be degreased in boiling liquid.

Choice of type of degreasing plant

The degreasing problems that may arise in factories and workshops are obviously many and varied but some general guidance can be given as to choice of plant.

First of all, it can be stated that vapour degreasing is suitable for all requirements except the following, where liquor or liquor-vapour degreasing is necessary.

(1) Vapour degreasing does not remove solid materials which are held in suspension in grease; the vapour removes the grease-bond but leaves the solid adhering to the work. If the work is suspended in briskly boiling solvent liquor, the solid materials are removed as fast as the dissolving grease releases them. As a result of this treatment the solvent, of course, becomes dirty and, if a perfectly clean surface is imperative, as on work to be electro-plated, then vapour treatment is necessary after the liquor wash and the liquor-vapour process is recommended. In a number of cases where dirt and grease are present together, vapour degreasing is sufficient because the grease-free dirt is easily brushed off.

(2) Light metal sections reach the temperature of the vapour before sufficient solvent has condensed to remove all the oil. This trouble can be overcome by allowing the work to cool outside the plant and then re-immersing in the vapour. However, it is

Operation of degreasing plant

It is assumed that the plant has been installed, charged with trichlorethylene and started up according to the maker's instructions. Soon after turning on the heat the solvent will boil, and the heavy vapour will rise in the plant to the level of the lower condensing coils.

Vapour degreasing

When dealing with a heavy article, this should be hoisted over the plant and steadily lowered into the vapour until it comes to rest on the perforated plate near the bottom of the tank. Oily condensate will stream from the work and the level of vapour may fall due to the condensing action of the mass of metal, but will gradually regain its former level. By the time this occurs degreasing is usually complete. The article is raised above the vapour level and dries immediately, except where solvent has been trapped in pockets. This liquor should be emptied immediately into the plant sump. Fig. 5 shows the rear axle of an omnibus receiving vapour treatment during routine overhaul.

Medium-weight articles such as pistons, con-rods, swivel pins, etc., should be handled in baskets wherever possible and lowered into and raised out of the plant by means of a hoist having a maximum speed of 10 ft. per min. By suitable manipulation of several baskets, a large throughput can be obtained from quite a small plant. Fig. 6 illustrates this method and shows a vapour

Fig. 5.—The rear axle casing of an omnibus receiving vapour treatment during routine overhaul. [Courtesy of I.C.I. Ltd.

degreasing plant used for the removal of pressing oils from a variety of components before welding.

Liquor-vapour degreasing

The lids of the plant are gently opened and the articles to be cleaned are lowered into the liquor compartment, where the briskly boiling solvent dissolves the adhering grease. If baskets are used they should rest on the perforated plate at the bottom of the compartment. Alternatively, the work may conveniently be suspended by jigs or wires from crossbars at the top of the plant. The length of time for which the work is immersed in the boiling liquor depends on the tenacity of the material to be removed.

The work is withdrawn gently and suspended for a few minutes above the liquor compartment in order to drain and cool slightly. It is then lifted over the division plate and hung in the vapour for a few minutes. Here, any traces of grease from the solvent in the liquor compartment are removed.

Fig. 7 shows a standard bench model liquor-vapour plant used for cleaning fountain pen nibs. Similar small plants are used by watch and clock manufacturers, scientific instrument makers, and are also found in laboratories and instrument workshops.

Liquor degreasing

The work is loaded into a suitable basket, which is then lowered into the first compartment and rested on the perforated plate near the bottom. After a few minutes the basket is gently raised above the liquor, drained and lifted over the division plate into the second compartment, where it receives a similar treatment. Finally, the basket and its contents are placed in the third compartment, which contains virtually pure solvent. Actual times of immersion in the various compartments are, of course, a matter for experiment, but two or three minutes is usually sufficient. The solvent remaining between the pieces is removed and recovered by placing the work on a draining rack above the vapour level for a few minutes.

Special plants

The foregoing account has dealt exclusively with standard trichlorethylene degreasing plants so that the basic operating principles should be clearly appreciated. Not every degreasing problem can be solved by a range of standard equipment and three examples of special plants will now be given which demonstrate the wide applicability and flexibility of the trichlorethylene degreasing process.

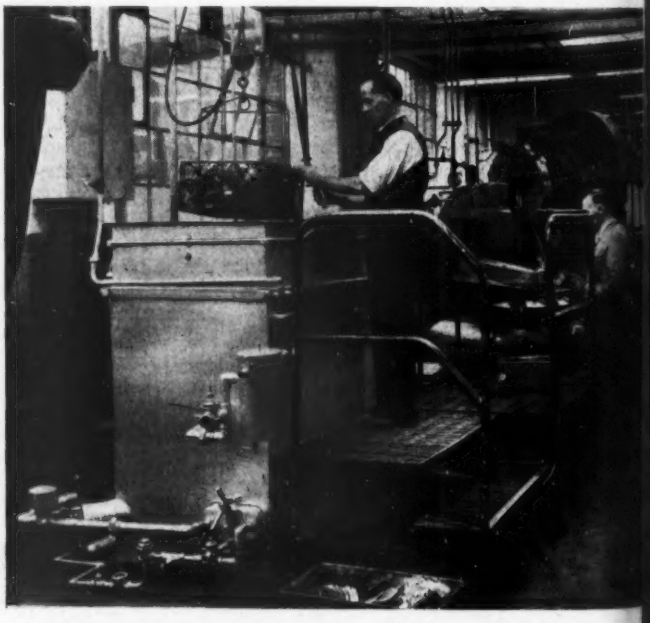


Fig. 6.—The removal of pressing oils from electrical components before welding.
[Courtesy of I.C.I. Ltd.

Continuous boiling liquor plants

Fig. 8 illustrates a continuous boiling liquor plant for the removal of machining oils from a variety of electrical components before plating. Near the plant are seen the various conveyor systems for carrying the work to and from the plant.

Continuous strip plants

These range from plants to degrease bright strip after rolling and before annealing, to plants which clean light strip running at a relatively high speed before finishing processes. A line of plants of this latter type is shown in Fig. 9.

Plants for long narrow objects

These are usually vapour-type plants. Occasionally they are provided with an auxiliary tank which collects pure solvent distillate. This solvent can be pumped through a flexible pipe with a long nozzle and directed on to the work.

Fig. 7.—A standard bench model liquor-vapour plant used for cleaning fountain pen nibs.
[Courtesy of Mentmore Manufacturing Co. Ltd., and I.C.I. Ltd.

Contamination of solvent

Oils and greases removed in degreasing are entirely miscible with trichlorethylene and go into solution in it. Most greases, oils, waxes and tallows, however, have boiling points and vapour pressures well above the maximum temperature of this solvent and they do not normally vaporize with it. However, as the sump solution becomes contaminated with these oils the temperature required to vaporize the solvent will increase. This might ultimately result in a heavily contaminated solvent giving rise to contaminated vapour and consequent inadequate degreasing. Large volume consumers of solvent often maintain a plant control laboratory where by means of a simple routine titration a check can be made for acidity or by distillation the oil/solvent ratio can be determined. The ratio of oil to solvent can also be determined quickly either by a simple thermometer or specific gravity check on the oil-solvent mixture. Redistillation should take place when the oil content rises to 40 per cent and this occurs at a temperature of 201.7° F. for trichlorethylene. As regards the specific gravity method the figure for lubricating oils generally used is of the order of 0.9, whereas trichlorethylene at room temperature has the much higher specific gravity of 1.45. Specific gravity measurements should always be made at the same temperature.

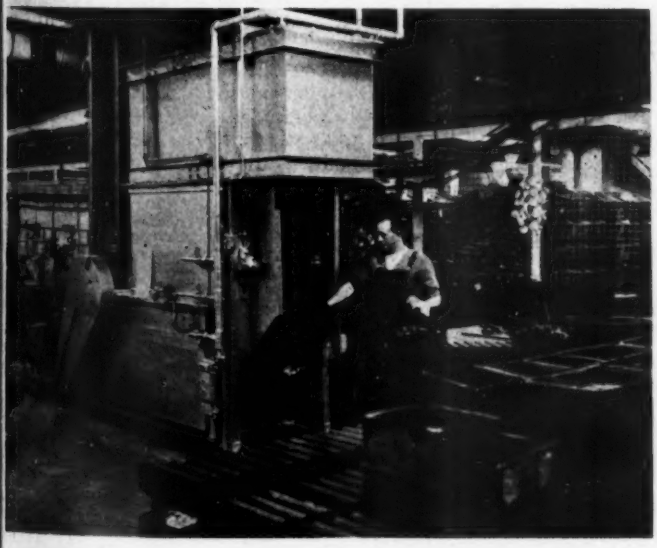


Fig. 8.—A continuous boiling liquor plant for the removal of machining oils from a variety of electrical components before plating.
[Courtesy of I.C.I. Ltd.

Fig. 9.—A battery of specially designed plants to give vapour and solvent washing treatment to continuous lengths of strip steel.
[Courtesy of I.C.I. Ltd.

Practically all vapour degreasers are designed to reclaim solvent from heavy oil contamination by a suitable distillation process. This normally necessitates a mere opening or closing of a few valves to re-direct condensed flow from the degreaser to a separate container or clean solvent compartment. In fact the degreaser during normal cleaning operation functions as a still. The so called " distillation sequence " is a modified step to separate the solvent completely from oil, and permit subsequent drawing off of the latter. Some multiple compartment machines are designed so that the oil residues from the boil compartment are either continuously or intermittently pumped to a separate still, adjacent to the degreaser, thereby providing rapid return of clean solvent to the rinse compartment. This procedure causes less interruption of the degreasing cycle and finds special application when the work parts are heavily coated with oil.

Health Factors

All the chlorinated hydrocarbons have some anaesthetic properties and will cause dizziness and nausea when inhaled in heavy concentrations. Extended breathing of excessive quantities will cause unconsciousness.

Medical authorities state that a vapour concentration of trichlorethylene in air not exceeding 100-200 parts per million is not likely to cause permanent harm. This is much in excess of the vapour concentration that should be normally encountered if operation is well conducted and supervised. About 50 parts of trichlorethylene vapour per million parts of air can generally be detected by smell. Thermal breakdown of trichlorethylene vapour can occur should it come into direct contact with a flame. For this reason it is not advisable to smoke in the vicinity of degreasing plants since vapour inhaled in this way is likely to be decomposed by the red-hot tobacco ash with formation of the poisonous phosgene gas.

Economic Considerations

The cost per unit weight of trichlorethylene is greater than that of an alkali cleaner and the capital cost of trichlorethylene degreasing plant may be greater than that of the corresponding alkali cleaning equipment. The real basis of comparison lies in the relative operating costs of the two processes and here trichlorethylene will usually be found to have the advantage. The trichlorethylene plant is small and self-contained; it occupies a minimum of factory floor space, its heating requirement is low, cleaning is rapid and the work emerges from the plant ready immediately for further processing, the solvent can be used over and over again and the plant merely requires topping up to replace solvent losses. The alkali process, on the other hand involves the use of a cleaning tank and a swill tank, with possibly a hot rinsing tank and a hot air-drying apparatus as well, it occupies a considerable area of the factory floor, requires a considerable total heat input, and, of course, the cleaner has to be replaced as it becomes exhausted.

Acknowledgements

In conclusion, the author would like to thank I.C.I. Ltd. for supplying information relating to their trichlorethylene degreasing plants and for the illustrations reproduced in this article. Thanks are also due to the Mentmore Manufacturing Co. Ltd. for permission to reproduce the photograph of the bench model liquor-vapour plant shown in Fig. 7.

FLOW PRODUCTION in VITREOUS ENAMELLING

as Exemplified in the Layout of a Modern Plant

described by A. R. PARKES

Introduction

THE new vitreous-enamelling plant of the Revo Enamel Co. at Tipton, Staffordshire is designed and operated on a completely time-controlled cycle for maximum production enamelling of one type of article—the one-piece sheet-iron cooker body and its components. The layout and disposition of plant was decided upon following visits by the chief executive to leading enamellers in this country, on the Continent and in America, and is thought to embody the best features seen, without some of the drawbacks which have become evident during the life of the installations inspected.

The shop is capable of enamelling just over 2,000 sets of cooker parts per normal double-shift week. It is designed also to embrace the enamelling of all types of domestic equipment in addition to the firm's own products, and can easily be adapted for enamelling of cast products. At present, it is only operated at about 50 per cent of its potential. When envisaging the possible limit of its capacity, it might be mentioned that the firing furnace is actually able to cope with over 2,000 sq. ft. of ware per hour.

Following the general conception of the plant in the early stages and consideration of the space available (17,920 sq. ft.), as well as routes inwards for sheet-iron parts from the press shops, and routes outwards of enamelled ware to assembly, a stage-by-stage layout was worked up on paper. This was followed by the arranging of a wall plan (Fig. 1) on which items of plant, cut out to scale, could be pasted. Finally, a three-dimensional scale model (Fig. 2) of the whole interior of the shop was developed and after some adjustment of the items to give proper working clearances at the various points, actual construction commenced. The whole shop, laid out much as was originally planned has now been in production for two years—long enough to prove the soundness and ingenuity of the original scheming.

OPERATIONAL CYCLE

The itemized layout of the shop is recorded in Fig. 1, in which the letters refer to plant items in the sequence of processing described in what follows; cross-references should also be made to Fig. 2, a photograph of the "3D" model. The whole plan is based on the receipt of complete sets of components at point A, which is the storage bank for sheet-metal work.

Pickle:

From position A, the ware to be enamelled is loaded on to a moving pendulum-type monorail chain conveyor and off-loaded at point B, situated inside the pickle shop. Here a body-unit and a complete set of components for a cooker are transferred as a whole directly into pickle baskets, lying on roller conveyors. These are moved around in turn to the hoisting position C, adjacent to the tanks (Fig. 3). The baskets of ware then pass through the pickle-treatment sequence: cleaner → hot swill → cleaner → hot swill → hot sulphuric acid (one of two tanks) → cold swill → neutralizer → hot swill → dryer → carrier frame—in a five-minute cycle, so arranged at present as to give a throughput of one set of cooker parts every 2½ min. The baskets are released at point D, again on to roller conveyor track and the ware is once more placed on the pendulum conveyor, the pickle baskets continuing to B, for repeating the cycle.

Dipping:

After pickling, the sets of components travel on the monorail to E, which is the dipping-tank area (Fig. 4), for applying the ground-coat. All ware is so treated, and then passes through an infra-red turbulent-air U-type dryer, F. The next stage is a ground-coat reinforcing booth, G, where the edges of the ware are sprayed with ground-coat material, finally being loaded, at point H, on to the furnace track, for ground-coat fusing. The latter operation is carried out in a continuous U-type

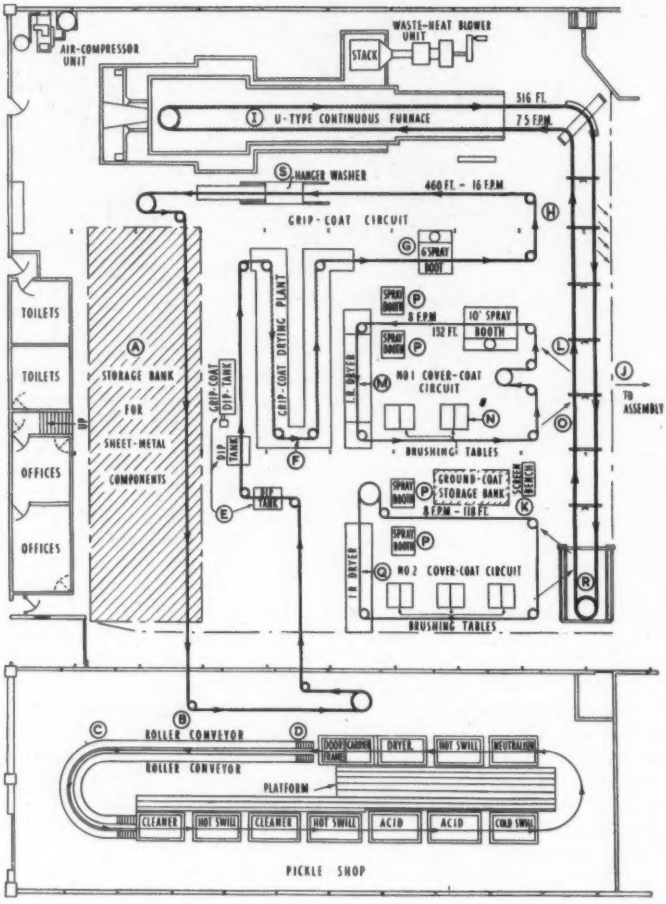


Fig. 1.—General layout of the new Revo enamelling shop, showing the main items of plant and the conveyor lines. (The letters denote processing sequence and are referred to in the text).

furnace, I, where the components are fired at 840° C. (see Fig. 5).

On leaving this furnace, ware to be finished in ground-coat only is off-loaded for inspection at point J, and then packed on stillages for transport by fork-lift truck to storage banks prior to assembly. About 2,000 sets of cooker parts are retained in this " buffer " store.

Cover-coat:

Ware to be further processed in cover-coat enamel continues past J, and small parts are unloaded opposite the ground-coat storage bank, K, where the ground-coat enamel is inspected, prior to cover-coat spraying. Pre-assembled cooker bodies are off-loaded at point L, for chain-conveyor-line spraying in water-wash spray-booths, as shown in Fig. 6. After spraying, the bodies pass through a second infra-red dryer, M, and are edge-" brushed " in the area N, before being re-loaded on the furnace conveyor at O, for passage to and through the fusing furnace, I.

Meanwhile, the smaller parts, after inspection, are distributed to smaller spray-booths P, for cover-coating with enamels of various colours, depending on the component. These are then dried in infra-red tunnel dryers, M, or Q, and then re-loaded on to the chain conveyor at points O, and R. This work next travels through furnace, I, and on to inspection point, J, where it is unloaded and crated on stillages or (in the case of defective items) is re-loaded for re-spraying.

Hanger Cleaning

From point H, empty hanger attachments on the chain conveyor pass through an automatic spray-washing booth, S (Fig. 7), to remove any surplus ground-coat. The hangers then continue to point A, for re-loading and recommencement of the cycle. For the hanger washing water at the rate of 1,000 gal. per hour is recirculated through multiple high-pressure jets.

PLANT DETAILS

Pickling Plant:

The pickling plant comprises a continuous loop served by 10-cwt. capacity Felco hoists, the latter specially screened and sealed against steam and acid fumes. There are ten 1,000-gal. tanks (the acid tanks being in duplicate) each 8 by 5 by 3 ft. 6in. deep. Monel-metal baskets are used. There is a service platform in the middle of the loop from which pickling operations are controlled.

In this section, all plant, ducting, steelwork, etc. is painted with rubberized protective paint which is reported to be giving very satisfactory

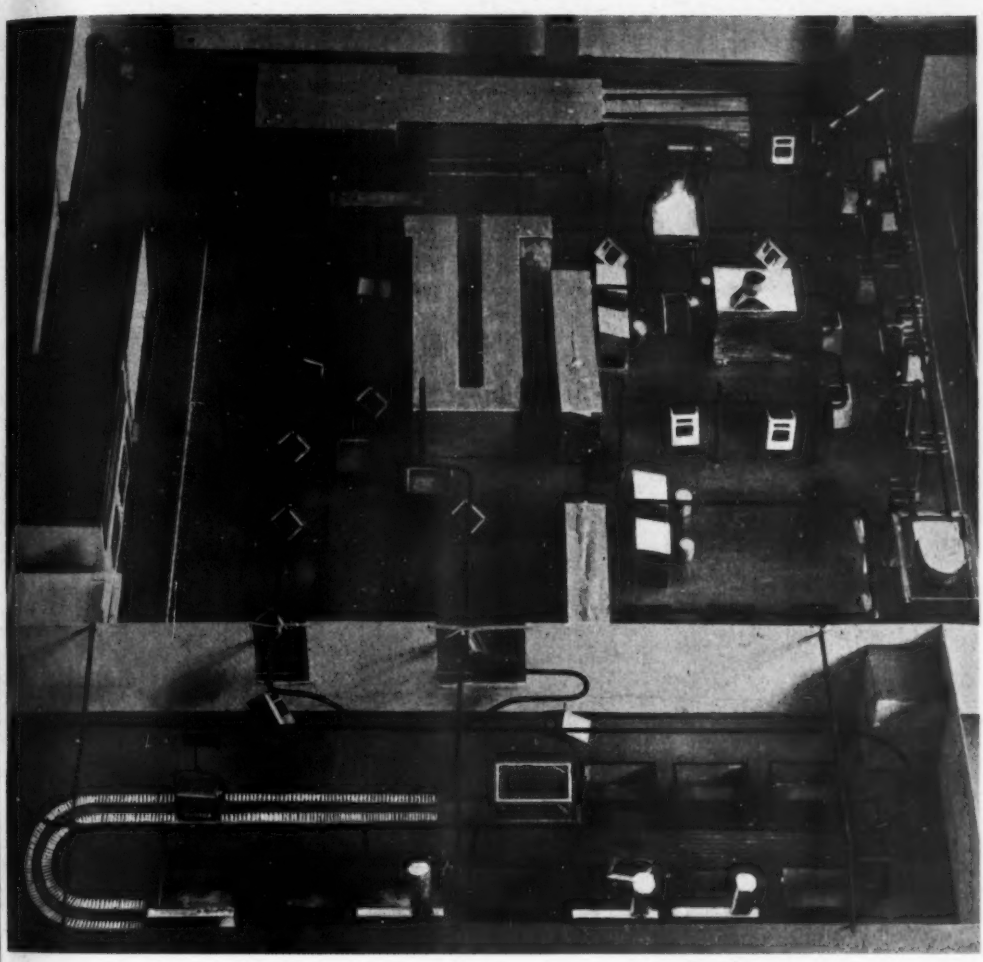


Fig. 2.—Photograph of the "3D" scale model of the new shop.

service. The acid tanks are rubber lined. All pickling plant was installed by A. E. Griffiths (Smethwick) Ltd., a very efficient feature of the installation being lip extraction of steam and fumes from the tanks.

Conveyors and Hangers:

The conveyor types, track lengths, speeds and hanger centres are given in Table I, and a portion of the main ground-coat conveyor (*a*) is shown in Fig. 8. The furnace conveyor, being of a heavy type, is supported from floor-built joists, but all the others are supported from the roof trusses. All are powered by Croft's variable-speed drive units and on the ground-coat conveyor, (*a*), there is a multi-speed motor variable by 5 ft. per min. Safety knock-out switch points are incorporated at various places on the conveyors. The hangers are used at 50 lb. loading each, but their safe working load is 75 lb. (the hangers themselves weigh 8 lb. each).

Fusing Furnace:

The fusing furnace, H, is a standard Ferro "Junior" model, with a Revo control panel, (Fig. 9). It is oil fired and has an average fuel consumption of 20.8 gal. per hour. The overall length of the fusing furnace is 75 ft., including pit and burners (9 ft.), and is divided into three zones; entrance—20 ft.; preheating—28 ft.; and fusion—18 ft. Air seals (Fig. 5) are used to minimize heat losses. The whole roof is

Fig. 3.—Pickling tanks and Monel-metal basket of ware. Note the exhaust from the lip of the tank on the extreme right of the picture.

Fig. 4.—Four stages in the ground-coat dipping and draining of a "Monarch" one-piece cooker body.

TABLE I.

Details of Conveyor Tracks (see also Fig. 1)

Conveyor	Supplier	Length in ft.	Speed in ft. per min.	Hanger Centres, in.
(*a*) Ground-coat ...	New Conveyor Co. Ltd. ...	460	16	48
(*b*) No. 1 Cover-coat ...		132	8	40
(*c*) No. 2 Cover-coat ...	Stewart Gill & Co. Ltd. ...	118	8	40
(*d*) Furnace	Ferro Enamels Ltd. ...	316	7.5	48*

*The furnace conveyor (d) has special, double-looped hangers, the main object of these being to keep the tool/ware ratio of the furnace load as low as possible.

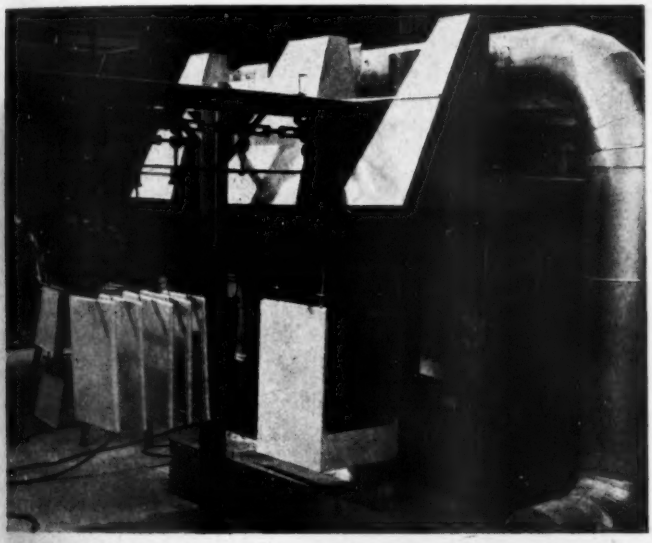


Fig. 5.—Entry (and exit) point of the continuous U-type fusing furnace for ground- and cover-coat. The air-curtain device to retain heat inside the furnace is clearly visible.

cut through by the conveyor hangers and sealed by fish plates. The hot-zone travel is 31 ft., which is equal to an equivalent box-muffle firing time of 4½ min. at the speed of travel quoted in Table I (this being used as a "yard-stick" for correct fusing).

Shop Heating:

Waste-heat from the fusing furnace is taken out at the recuperator and used for shop heating in the winter months, and is piped to the dryers (to replace the gas-heated panels) in the summer. Shop temperature is electronically controlled by mixing cold inlet-air, shop air, and heater-air to maintain about 62 to 65° F. This control

Fig. 6.—Water-wash spray-booth for cover-coat enamel application.

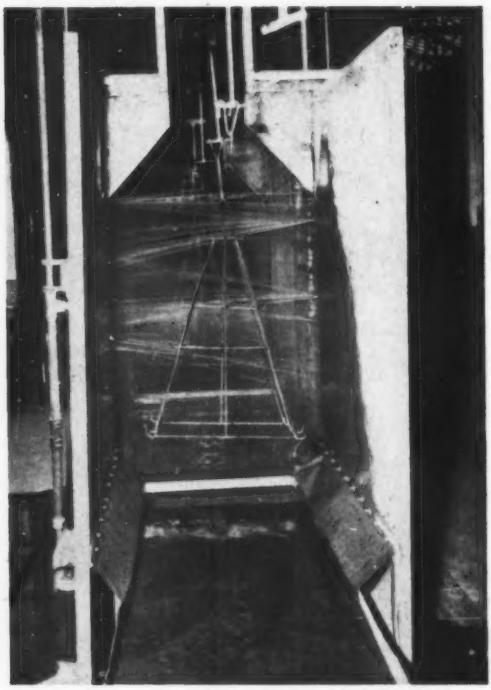


Fig. 7.—End view of the automatic high-pressure water-spray booth for cleaning hangers. It is situated at the end of processing on the cover-coat pendulum conveyor.

is further supplemented by "electric-eye" door controls at the shop entrance and exit which are actuated as trucks approach and leave.

Infra-red Dryers:

The U-type dryers, furnished by Stewart Gill and Co. Ltd., consist of a first leg of infra-red gas-fired heating panels, and products of combustion from these are collected in a heat exchanger and circulated in a turbulent manner in the second leg—the principle being to heat components quickly and then dry with hot air. Each leg is approximately 32-ft. long. The most recently installed dryer, P, has a heat exchanger and re-circulating hot air.

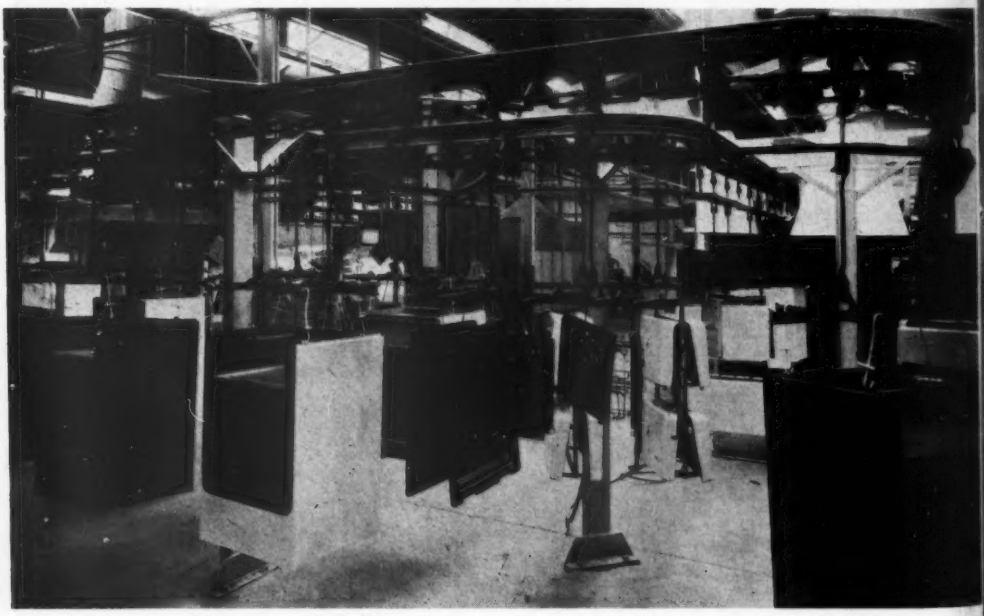
For spray-booths, the water-wash type are employed wherever possible in order to keep down dust and to safeguard the health of operators. The management has gone to considerable lengths and expense in trying to prevent the formation of dust from the concrete floors, without, as yet meeting with complete success.

Enamels

Without exception, all the cover-coat enamels used in the plant on sheet-steel ware are titanium based and comply in acid-resistance with British Standard Specification 1344. They are all bought-in and a feature that will be remarked upon by enamellers is that both ground-coat and cover-coat enamels are fired at the same temperature.

(*Continued in page* 368)

Fig. 8.—Part of the new Revo enamelling shop, showing in particular, part of the main ground-coat conveyor which is 460-ft. long.



A Students Guide to Examination Courses in Metal Finishing

II. Intermediate (*Cont.*)

Compiled by A. ALEXANDER

Lack of success in passing examinations arises almost as frequently from failure to apply knowledge properly as from failure to acquire knowledge. This series of articles is intended to assist actual and intending entrants for the City and Guilds Certificate Examinations in Metal Finishing to answer examination questions in the most effective manner.

(*Series continued from page 230, May, 1955*)

Corrosion

IT has been said that no sooner has a piece of metal been produced from the native ore than it starts a constant endeavour to revert to its original condition. In point of fact, most metals are attacked by acids, alkalis or salts present in the atmosphere or other environment and this attack, when it takes place due to the effects of normal service conditions, is called corrosion.

If a piece of zinc is placed in a solution of hydrochloric acid, it will be attacked, liberating hydrogen and dissolving in the acid to form a solution of zinc chloride. This may be expressed by the equation:—

$$Zn + 2\,HCl = Zn\,Cl_2 + H_2$$

It will be seen in this case, that the zinc replaces the hydrogen of the hydrochloric acid as one might expect from their relative position in the electrochemical series, previously described. It is, however, a fact that if a sample of an extremely pure zinc is used, the speed of the reaction is very much reduced. Most of such reactions are electrochemical in nature, and in order for them to proceed there must be very slight differences in the metal surface at different points, so that one point may become anode and another cathode. Under these circumstances a small current will flow through the metal from the cathodic portion to the anodic portion and this will cause the metal to dissolve.

In many cases this action is set up due to the effect of slight differences in either the position or in some cases the structure, of the metal surface. It is also possible, however, for the same type of small cell to be produced due to slight differences in solution concentration or composition. For example, if a small drop of solution is placed on a metal surface, there is rather more oxygen from the air dissolved in the outer part of the solution than in the centre, and this in itself may cause a slight difference of potential from the centre to the edge, so that current may flow.

Corrosion due to the various corroding agents in the atmosphere is invariably due to some such cause, for example, even on a sheet of relatively pure metal, the fact that the concentration of the corroding agent varies from place to place on the surface, may give rise to an electrolytic attack. Alternatively, a piece of metal which has impurities embedded in it, has properties which vary over its surface, and this again may set up a cell. A similar condition arises in the case of two dissimilar metals in contact, for example, if a piece of zinc is connected to a piece of copper, and they are placed in a solution of common salt, the zinc becomes anode and the copper cathode, and the zinc will dissolve, leaving the copper. This will also happen if a piece of steel sheet has a hole drilled in it, in which is placed a zinc plug. If this combination is immersed in a salt solution the zinc will dissolve, while the steel round the zinc will not be attacked, although the more remote part of the steel sheet will start to rust. This is because the zinc makes a small cell with the steel, current flowing through the steel to the zinc and making the zinc the anode of the cell, so that it dissolves into the solution. The current then flows back from the solution to the steel but the majority of the current flows to the steel at the nearest point to the zinc, so that at a significant distance from the zinc plug, there is not a sufficiently high potential at the surface to prevent the steel itself dissolving into the solution, due to the setting up of a number of very small local cells on its surface.

The atmosphere is, of course, composed principally of nitrogen and oxygen together with some carbon dioxide. In addition, however, in most industrial districts there is a fair amount of sulphur compounds and possibly small quantities of nitric acid, while in marine districts there is usually a certain amount of chloride. In the presence of water, which is always present in the atmosphere in the form of vapour which at times may condense on cool surfaces, these materials produce conducting solutions which act as electrolytes. Due to the action of the small cells formed, the metal will dissolve into the solution. Since the layer of solution on the surface of the metal is

usually quite thin, it can easily pick up a certain amount of oxygen from the air, so that in the large number of cases the final corrosion product will be an oxide. For example, iron, zinc, nickel and many other metals, when exposed under normal atmospheric conditions, will soon produce a film of oxide on the surface. Those metals which appear at the top of the electro-chemical series, for example, magnesium and aluminium would be expected to oxidize much more quickly than those nearer the centre, such as iron, but if a piece of aluminium sheet and a piece of steel sheet are exposed to similar outdoor conditions, after a time the aluminium shows little or no attack, whereas the steel is badly rusted, that is to say it is covered with a layer of ferric oxide. This may at first appear contradictory, but in point of fact the aluminium is more easily oxidized than the iron. In fact, it is so easily oxidized that it is practically impossible to get an oxide-free surface. But, in the case of the aluminium, the oxide forms an adhesive coating, which protects the underlying metal and so prevents further action. With iron, however, this is not so, the oxide formed under the conditions described is a loose non-adherent coating which does not protect the underlying metal, and so the action will continue until all the iron is rusted away. Many metals which appear to resist corrosion quite well in fact do so, not because they are not easily oxidized, but because the oxide film protects the underlying metal. Chromium, for instance, will resist corrosion and tarnish extremely well itself, simply by virtue of this very thin invisible oxide film. If in some way this film is removed, then the metal will dissolve away quite quickly.

The metals at the bottom of the electro-chemical series such as gold and platinum, do not oxidize easily at all, so that there is very little attack on them by the ordinary corrosive agents, and, in fact, metals like platinum and rhodium are extremely difficult to dissolve in any chemical re-agents. Such metals, therefore, will resist corrosion and can be used to protect other metals against corrosion.

It is important, therefore, for the student to realize in the first place, that the majority of metals will be attacked chemically by moist atmosphere, sea or tap water and that this attack may be accelerated by other metals with which they may, from time to time, come in contact. It is also important to realize that this attack is electro-chemical in nature and that anything which tends to increase the difference in potential between two adjacent spots on the surface of the metal will tend to increase an attack. It is also important to remember that if the product of the attack, that is to say the resulting salt or oxide, forms a protective layer, the attack may be stopped, but if it does not do so, the attack will continue as long as the corroding agents are present.

Economically, the corrosion of metals is enormously important, and it has been estimated that the cost of this annually runs into many hundred millions. It is, therefore, very desirable that when machines or structures are constructed of metal, every precaution should be taken to prevent or minimize corrosion, and for this purpose electro-deposition may often be used.

Corrosion Prevention

Keeping in mind the facts already discussed, it will be apparent that there are several methods by which a metal can be prevented from corroding. In the first place, it can be isolated from coming into touch with any media which is likely to attack it, for example, it can be sealed in a vacuum container or put in a perfectly dry atmosphere in a desiccator. Under such circumstances it will be obviously quite impossible for any type of cell to be set up, but for ordinary purposes, such methods cannot be used. Resort may therefore be made to coating the metal with some material which will prevent the corrosive agent coming in contact with it, as for instance, a heavy coat of Vaseline, or some similar material, or several coats of paint. Such methods will protect the steel as long as the coating remains intact. Such coatings however, may not resist the conditions under which the article is to operate, and if they become rubbed off or damaged the article will, of course, be attacked. For many purposes, therefore, instead of coating a corrodable metal with grease, or similar substance, it may be preferable to coat it with an adhesive layer of another metal, which will not corrode, or which will be less corrodable under service conditions For example, brass which will normally be attacked by either chloride or sulphur compounds present in the atmosphere, may be coated with a heavy deposit of gold, which will withstand such attack. So long as the layer of gold completely encases the brass article, it will protect it and no corrosion will take place.

Alternately, the coating may consist of another metal which will actually corrode preferentially. It was pointed out earlier that if a piece of steel sheet has inserted in it a zinc plug, the zinc will corrode in preference to the steel and in doing so, will protect the steel adjacent to it. Thus, if a steel sheet is plated with zinc all over, then the zinc will protect the steel, although it will itself corrode away in time. No attack on the steel will take place until the zinc has been eaten away. Even when there are a few bare patches of steel exposed, the zinc will still protect them until they reach a certain size.

There are thus two different methods of protecting, for example, a piece of steel, (*a*) it may be coated over with a layer of protective metal which does not corrode so easily as the steel. This would be called a cathodic coating because if the steel becomes exposed and a cell is formed between the two coatings, the steel will become the anode and will corrode very quickly. Thus the cathodic coating is only effective if it forms a completely sealed envelope over the entire surface of the metal. (*b*) the steel may be coated with some metal, for example, zinc or cadmium, which will corrode preferentially to the steel, although at a lower rate. Such would be an anodic coating and even if small points of steel are exposed due to scratches or faults in the coating, they will still be protected though there will be a tendency for the corrosion of the protective metal to be enhanced at these points, due to the electrolytic action between the two.

It is important that a clear picture of these two types of coatings should be formed. Thus one could see in the case of coatings such as zinc, or cadmium, the structure and freedom from porosity is very much less important than it is in the case of a coating of nickel, which does not corrode preferentially to steel.

In some cases, it is possible to reduce the corrosion still further by treating an anodic coating such as zinc with some material that will form a protective layer on its surface. For example, a piece of zinc-plated steel will resist corrosion in an industrial atmosphere fairly well, but in a warm humid atmosphere the zinc surface will be quite quickly attacked. If, however, the zinc-plated article is treated in an acid chromate solution, the solution forms a compound of zinc and chromium on the surface which produces an adhesive film and protects the zinc from further corrosive action. This is the basis of the "passivating" process. Steel itself may be protected in a similar manner by the use of phosphates, which form the basis of many industrial proprietary protection processes of this type.

Types of Metal Finishing

The majority of metal finishing processes are devised (*a*) to protect the underlying metal, and, (*b*) to improve its appearance. Attention will here be paid first to those processes used for protection. In this Course paint is not included and therefore methods involving the use of paint or organic materials such as grease, wax, etc., will not be dealt with.

There are, therefore, the following possibilities:

1. The metal surface may be protected by coating it with a layer of some metal which will corrode preferentially to it; or

2. It may be protected by forming a complete envelope of material which will resist the corrosive conditions under which the article is required to perform. Such a coating may be a suitably corrosion-resistant metal or it may be some type of chemical compound which will afford protection from the corrosive agents in question.

1. In the case of steel which is the metal most usually required to be protected, this may be coated with another metal which will corrode preferentially, for example, aluminium, zinc or cadmium. This coating can be carried out in a number of ways. Aluminium is usually applied to steel by metal spraying, involving the use of a special spray gun in which the aluminium in the form of wire or powder is fed into an oxy-, hydrogen flame and then blown with compressed air on to the surface of the metal. An Intermediate student in the examination is not required or expected to have any detailed knowledge of the design of this gun, but he should be generally aware of the process and how it is operated. It is, of course, necessary to obtain an adhesive deposit of aluminium on the steel surface and this can be obtained if the steel surface is correctly prepared for example by grit-blasting. The aluminium or other metal to be applied by this method must be sprayed on to the surface as soon after the grit-blasting process as possible.

Zinc may be applied, either by metal spraying as above, by hot-dip galvanizing, which involves dipping the steel, previously cleaned and coated with a suitable flux, into a bath of molten zinc, or by electro-deposition. There is also another process called Sherardizing, which can be applied to small articles, in which the articles are treated in a box full of zinc dust which is heated by means of gas burners to a temperature somewhat below the melting point of zinc. A choice of these processes will depend generally on convenience, cost, etc., and the type of article which has to be treated. For example, to coat a large structure, such as a bridge or part of a building, cannot easily be achieved by placing it in a plating bath or even in a pot of molten metal, and it is, therefore, necessary to spray it. Some articles, might be distorted or their structure upset by heating them, and in such cases they have to be coated by electrodeposition.

Cadmium may also be used to protect steel and this is normally applied by electrodeposition, as it is the most convenient method.

2. The protection of steel by forming on it an envelope of some metal which is less readily corrodable, normally makes use of either tin, copper, nickel, or perhaps in special cases, one of the precious metals. Certain alloys are also used for this purpose.

Tin can be applied to steel either by dipping the steel into a molten bath of tin, or by electro-

deposition. A very large quantity of steel sheet is tinned and originally this was all done by hot dipping, but lately a good deal of this plate has been produced by electrodeposition, the steel being tinned as a continuous coil of strip which is cut into sheets after tinning. Copper and zinc are also usually applied by electrodeposition.

A number of alloys are also used for protecting steel, among which may be mentioned brass, tin-zinc, and tin-nickel. These alloys are again usually applied by electrodeposition.

Steel may also be protected by forming a chemical layer on the surface. The majority of these layers depend on a coating of phosphate produced in solutions containing phosphoric acid and metal phosphates, for example, zinc or manganese. These solutions attack the surface of the steel and form a protective layer of basic iron phosphate. This layer not only gives a certain amount of protection directly to the steel, but is also capable of taking up such materials as oils, grease, wax, paints, etc., which seal the layer and give added protection.

Other metals may be protected in a similar manner to steel, for example, brass or copper can be nickel-plated, zinc and zinc-based die castings may also be coated with nickel or may be treated with a chromating process. Aluminium, as previously mentioned, tends to form a protective oxide layer on its surface without any treatment, but this layer may be considerably strengthened and its protection enhanced by making the aluminium the anode in a solution of chromic or sulphuric acid, for a short period. This produces a relatively thick adhesive layer of alumina on the surface which will also take up a number of organic dies so that finishes of various colours can be produced.

Decorative Finishes

For many purposes the appearance of a metal may require to be changed, for example, tableware may be required to have a pleasing white finish, such as would be exhibited by a piece of solid silver. For this purpose, therefore, the majority of tableware is silver plated. Silver also has the advantage that is does not corrode easily, although it tends to tarnish, particularly in the presence of sulphur and under such circumstances a very thin black film forms on the surface. For some ornamental objects this film is actually used to produce a pleasing finish, for example, the article may be dipped in a solution of potassium sulphide to form a thin dark film and then the film may be " relieved " by brushing some of it away so that the silver shows through. This type of finish which could be called a chemical colour, is often used for artistic objects and is known as oxy-silver. The finish itself, however, has little protective value as if left about for any length of time the bright silver portions will generally become dull and the appearance of the article will be spoilt. It is usual, therefore, to apply a final coating of lacquer to protect the surface. Tableware, however, cannot be lacquered, and therefore it must be cleaned from time to time. This cleaning, however, could be obviated by putting a very thin coating of a non-tarnishable metal, such as platinum, palladium or rhodium on to the surface of the silver.

One of the most popular decorative finishes today is chromium. This metal, again by virtue of a very thin oxide film which forms on the surface, remains practically untarnished by air or under normal atmospheric exposure. Unfortunately, however, chromium itself does not provide a very good protection to the underlying metal because thin coatings of chromium are very porous and thick coatings of chromium tend to crack. A piece of steel plated directly with chromium, will tend to corrode preferentially at the pores in the coating. This action will take place quite quickly and very soon the steel will be corroded away underneath the chromium and the chromium will flake off. In order to prevent this action, it is usual to apply a moderately thick coating of nickel to the steel prior to chromium plating. If the chromium is then plated on to the nickel surface, the nickel, which is far more resistant to corrosion than steel, will corrode little if at all, and a finish, which is both decorative and protective, will be obtained. It is, of course, important that the nickel shall be thick enough, since a thin nickel coating is again porous and is also liable to mechanical damage. For a coating of this type to be satisfactory, it must, therefore, be continuous, free from pores and imperfections, and thick enough to resist the required service conditions.

It is, of course, obvious that the surface of these decorative coatings shall be bright and highly polished, otherwise the required appearance will not be obtained. Since in the majority of cases the deposits applied are relatively thin, usually not much more than one thousandth of an inch and sometimes very much less, it is obvious that a good deal of the polishing, if not all of it, must be done before the article is plated. A light polishing process (usually called finishing) may, however, be required after the plating process, although there are today a number of special solutions which will produce bright deposits of many metals.

Alloy Layers

Where one metal is being applied to another by metal spraying or electrodeposition, there is usually a sharp demarkation between the basis

metal and the layer of applied metal. If, however, the metal is applied by hot-dipping, an alloy layer will often be formed at the interface between the two metals and this layer may produce certain effects. In some cases the layer may be relatively less corrodible than the metal being applied, but is probable that it will be rather more brittle. Thus, in the case of a steel wire coated with zinc, by hot dipping, the alloy will form a brittle layer which will tend to crack the wire on bending. These alloy layers also often make the estimation of the thickness of the coating more difficult to carry out.

Thickness of Coating

When metal is applied by means of a spray gun, it will be obvious that the longer the gun is directed at one part of the article the thicker the coating of metal will be. Thus, it will be largely a question of skill of the operator whether a uniform coating can be built up over the whole article. When an article is being coated by hot-dipping, the layer will normally be fairly uniform, except where the draining of the metal from the article as it is being withdrawn from the pot may produce slight thickening.

When the article is being coated by electro-deposition there will be a tendency for the deposit to be thickest at the outstanding portions of the article. This tendency will depend on the "throwing power" of the solution and will vary with different solutions.

It is obviously desirable to produce as uniform a deposit as possible, expecially where corrosion alone is being considered. In cases where abrasive wear is also a factor, it may be desirable to have somewhat thicker coatings of metal on those portions of the article from which it is likely to be worn preferentially, for example, on the outside of the bowl of a spoon. Normally, however, it is desirable to keep the coating as uniform as possible in thickness, though this is by no means always possible. Most specifications call for a certain minimum thickness on the article, but since on awkwardly shaped articles it may be extremely difficult to obtain such minimum thicknesses, in deeply re-entrant portions, it is usually specified that tests may be made only at those points which can be touched by a ball 1 in. in diameter.

A candidate for Intermediate examination will be expected to have a clear idea of the nature of corrosion of the commoner metals, particularly corrosion by the normal atmosphere. He will also be expected to be able to set out briefly the various methods of protecting metal from this effect and to be in a position to discuss how these methods should be carried out. Finally, he may be asked what factors he would take into consideration in choosing one of these methods.

The choice of the method to be used will depend on several factors. In the first place one has to consider the nature of the article to be protected and the metal of which it is made. As previously mentioned, quite different methods would have to be adopted in dealing with a 100 ft. long steel girder weighing perhaps some 5 tons, as against, a 2BA brass screw. Consideration must also be given to the type of service for which the article is intended, some articles may be exposed to fairly severe corrosive conditions, and at the same time may have to withstand a certain amount of abrasive wear. For example, a bumper bar or hub cap of a car may often come in contact with sea water or salt solution from salt placed on frozen roads, and will also be bombarded from time to time with small stones and dust particles.

Electric light fittings intended for use in a normal house, will not be exposed to such bad conditions and the fitting itself may be made of some material, for example brass or copper, which is less likely to corrode than the steel bumper bar. Finally the appearance of the article must be considered. This may often be specified by the customer. Alternatively, the article may not show, for example, it may be a nut on the inside of some engine and therefore its appearance does not matter.

Normally, when if it is required to protect a steel article against corrosion alone and not to provide a bright finish, an anodic coating such as aluminium, zinc or cadmium will be chosen. Aluminium is mostly used for structural work, zinc protects steel well in industrial atmospheres, particularly where it is fairly dry, whereas cadmium is better in a marine or tropical atmospheres. Zinc, with the passivated coating may be substituted for cadmium under the latter circumstances. Cadmium, however, is used on electrical aparatus because it is easy to solder to it, but again an alloy of tin and zinc may be substituted for this purpose.

For purposes where the article may come in contact with food, tin is usually preferable because it is non-toxic. Cadmium should never be used under these circumstances because certain people are susceptible to very small traces of cadmium and poisoning may result. For decorative coatings, steel is normally protected with nickel, which is usually flashed with a thin coating of chromium. In some cases coatings of brass or copper may be used, but these will require further protection by lacquering if they are to remain untarnished.

Copper, brass or nickel-silver articles are generally finished with silver, gold or rhodium. Much will depend on the use to which they are

(*continued in page* 368)

Flow Production in Vitreous Enamelling
(*Continued from page* 362)

Silk-screen processes are used for lettering work in the Revo enamelling shops in preference to transfers, and the firm has fostered considerable skill in making their own photographic silk screens.

Staffing and Working Systems

Under the general manager of the whole enamelling department, there is a shop superintendent and one foreman only on each shift in the shop described; (two eight-hour shifts are worked). Additionally, in the other (and older) enamelling shop of the firm, which utilizes box-muffle furnaces, there is a second foreman. Two chargehands and 150 operators comprise the labour force of the two plants, that is, 100 on the older plant and 50 on the new. Of the total, about 20 per cent are women, mainly engaged on edge-brushing.

The payment system adopted eliminates the necessity for overmuch supervision as it incorporates group-bonus arrangements based on work finished and passed inspection; *i.e.*, a "target" is set for the basic wage and any production exceeding that is paid 100 per cent. Another helpful feature is the establishment of inspection staff completely independent of the production shop. The system of payment eliminates any tendency to produce ware requiring re-processing and is most successful in keeping down scrap.

Conclusion

In concluding this account, thanks are due to Mr. H. G. Turner, and the superintendent Mr. W. O. Hannah for help and hospitality accorded the writer during its preparation and for the candid manner in which all information requested was supplied. They are both confident of the economics of their processing in the new shop and can be justly proud of their efforts. Thanks are also accorded to the directors of Revo Electric Co., Ltd. for permission to publish domestic details of the plant and methods of working, with such complete freedom.

Fig. 9.—Control panel for the Ferro continuous fusing furnace; this was built by Revo.

A Students Guide to Examination Courses
(*continued from page* 367)

to be put. Silver is relatively cheap. Rhodium is preferable as it produces a non-tarnishable coating, but its high price limits its use. If a rhodium finish is desired, it is usual either to silver or nickel plate the article first. For electrical switchgear, silver, gold or rhodium are also used and in the majority of cases the size of the parts to be treated are small so that the expense can be kept within reasonable limits.

A candidate for the examination will be expected to be able to discuss these various factors and to be able to suggest a suitable finish for any type of common article. In putting forward his finish, he should make it quite clear how he arrives at his decision thus, if he is asked what finish he would apply to the chassis of a Radio Set, and he decides to apply a cadmium finish, he should point out that his decision is based on the fact that cadmium will give efficient protection under the conditions of service if a satisfactory thickness (.0003in.) is used, that its appearance is pleasing, being whitish in colour, and that it is easy to assemble the apparatus since one can solder directly on to the coating. Alternately, if he feels that for this purpose a passivated zinc coating may be more satisfactory, he should point out that such a coating will give sufficient protection, but that although it may be more difficult to solder to it than cadmium, the cost of the metal will be very much less and that this will more than offset the additional labour involved. He may also point out that although the appearance may be less pleasing, appearance is not the primary factor since the chassis is in the inside of the set and is not normally seen. It should be pointed out that in such questions a candidate will be marked rather on the manner in which he takes his decision, than on the actual decision taken. For example, in the above question both processes are used in industry and both are satisfactory and therefore either answer could be considered right. Alternatively, a candidate may suggest more than one finish, pointing out the pros and cons of each and saying it will depend to a large extent on local factors which he would adopt. (*Series to be continued*)

FINISHING NEWS REVIEW

A NEW plating laboratory, built by the International Nickel Company Inc., and equipped with the only fully automatic pilot plating plant in the world was opened recently at Bayonne, U.S.A. This pilot plant offers to industry for the first time an opportunity to test both new coatings and new processes on a scale as close as possible to an actual industrial plating plant. A fully automatic plating line has been constructed capable of producing coated metal test panels in large numbers with an extremely high degree of control to assure uniformity. These panels, together with data obtained in their production, provide the plater with accurate data on new types of coatings or plating methods.

The automatic equipment, which is located in the main section of the laboratory building, (the latter occupies an area 145 ft. long by 65 ft. wide) has provision for 13 different stages of plating and/or cleaning. The tanks have a 400 gal. capacity and include rubber-lined, lead-lined and unlined steel types to cover a variety of plating needs. The plant is completely automatic except for loading and unloading and can be used in either single or double line operation for handling work up to 3 ft. in cross section. It can be operated entirely from a central panel board where time, current and voltage for each stage of a cycle can be observed and controlled. Power for cleaning and plating operations is supplied by a bank of 6 rectifiers, each rated at 1,000 amp at 12 volts, and 2,000 amp at 6 volts. The machine is equipped with fume exhausters at each station.

An outstanding feature of the plant is its great flexibility. The tanks are designed for simple handling with a lift truck and can be quickly moved in any desired sequence. The transferring and conveying mechanism permits work to remain stationary at any given station for as long as desired. Times may vary from as little as 5 seconds to as much as several hours, or even days. Although the machine was designed primarily for automatic operation, it also may be operated manually.

The manual plating line consists of 18 stations and is equipped with rubber- or lead-lined tanks and steel rinse tanks. They range in capacity from 100 to 300 gal. and can be placed in any sequence desired. The equipment includes pumps and filter presses for continuous filtration of solution, a cathode agitator, a variety of immersion heaters and several heat exchangers. Current is supplied by seven rectifiers ranging in capacity from 300 amp at 12 volts to 2,000 amp at 6 volts. Each station in the manual line is equipped with a means of exhausting toxic or noxious fumes.

The bench-scale laboratory, which is fitted with a fume hood, has two laboratory work benches 12 ft. long and 3 ft. wide. The benches and hood are equipped with compressed air, burner gas, hot and cold tap water and demineralized water. Solutions are heated with immersion-type heaters, sheathed in either Pyrex, quartz or nickel. Current is supplied by 12 portable rectifiers connected to an automatic voltage stabilizer. These range in capacity from 25 amp at 12 volts to 300 amp at 6 volts. Automatic timers are available for improved accuracy. Other facilities include a polishing and buffing room, equipment for salt spray testing and a controlled humidity room for the storage of metal.

The work of the plating section of the Bayonne Research Laboratory is primarily to find new uses for nickel, to improve the properties of nickel coatings, and enhance their durability and protective value.

Research is now being carried out in co-operation with container manufacturers and their suppliers of can stock, on the merits of thin nickel plating for can coatings. Illustrating a typical application for which the automatic plating machine was especially designed, this canning development requires large quantities of identically plated sheet steel. By the use of accurate timing devices, it is possible to produce any number of similar samples or combinations of electro-deposited coatings over a wide range of thicknesses. This feature also makes the plant expecially suitable for the production of large quantities of plated corrosion test panels frequently required in co-operative technical society test programmes, such as those carried on regularly by the American Society of Testing Materials and the American Electroplaters Society.

Some outstanding items being developed in the laboratory are a hard nickel bath for reclaiming worn and mis-machined parts; an all-chloride nickel bath for producing medium hard deposits: methods are also being developed for making composite metals including nickel-clad ferrous articles, and for nickel plating with insoluble anodes. Fundamental research is being carried out on the mechanics of the weathering of electrodeposited nickel, and pioneer research is being conducted in the field of high-speed plating in which it has been demonstrated that sound nickel coatings can be plated at the rate of approximately 4.0 mils per minute.

METAL FINISHING ESSAY COMPETITION

AS a further means of pursuing one of its primary objects, the provision of a medium for the dissemination of technical information on metal finishing and related subjects, the Institute of Metal Finishing has revived in a modified form the competition for the William James Memorial Prize, awarded in memory of the first honorary treasurer.

The original competition, which was allowed to lapse on the outbreak of the war, was restricted to persons not exceeding 21 years of age (later revised to 25 years) and was thus designed primarily for students.

In an attempt to attract entries from those engaged in the practical side of the industry, the competition has been divided into two sections *viz:*

A. Essays from a theoretical or technical standpoint on any aspect of metal finishing or a related subject. Age limit 25 years.

B. Essays based on practical knowledge or experience of any branch of metal finishing or a related subject. No age limit.

A first prize of ten guineas and a second prize of five guineas, subject to entries being of sufficient merit, will be awarded in each section. Entries, of preferably between 1,000 and 5,000 words, should be sent to the Hon. Secretary, Institute of Metal Finishing, 32, Great Ormond Street, W.C.1., marked "Essay Competition" to arrive not later than October 31, 1955.

TECHNICAL AND INDUSTRIAL APPOINTMENTS

Mr. L. E. Geering and Mr. A. W. Putnam have been appointed directors of the **Carrier Engineering Co., Ltd.**

* * *

Mr. S. L. Waide has been appointed general manager of the chemicals division of **Newton, Chambers & Co., Ltd.**

* * *

Mr. L. W. Johnson has been appointed assistant manager of the development and research department of the **Mond Nickel Co. Ltd.** Dr. E. C. Rhodes has been appointed assistant to the manager of the department, but will remain responsible for its precious metals activities.

* * *

Mr. A. W. Brace has left the Aluminium Development Association to take up an appointment with **Aluminium Laboratories Ltd.**, as section leader of the metal finishing laboratory.

* * *

Mr. Peter Smith, A.R.I.C., and Mr. Philip Shaw, B.Sc., A.R.I.C., have been appointed joint managing directors of **Acorn Anodising Co. Ltd., Acorn Products Ltd.**, and **Acorn and Lumium Sales Co. Ltd.**

Shell Chemical Expansion

DUE to the rapid growth of Shell's chemical activities and to facilitate the execution of plans for further expansion, all its chemical manufacturing and marketing activities in the U.K. and Eire are to be concentrated in one company, to be called Shell Chemical Co. Ltd.

The new company, which has an authorized capital of £10 million, will take over the activities of Shell Chemical Manufacturing Co. Ltd., and Shell Chemicals Ltd. These include the manufacture and marketing of detergents, solvents, resins and agricultural products and a wide range of chemical intermediates. The chairman of the new company will be Mr. F. A. C. Guepin, a managing director of the Shell Petroleum Co. and a director of many other companies connected with the Royal Dutch/Shell Group.

PANEL FINISHING ON DIESEL RAIL CARS

FURTHER to the note published on this page of the April issue, describing the tool developed for London Transport for the dressing of weld beads on light-alloy sheets, the following description of a similar procedure adopted by British Railways is of interest.

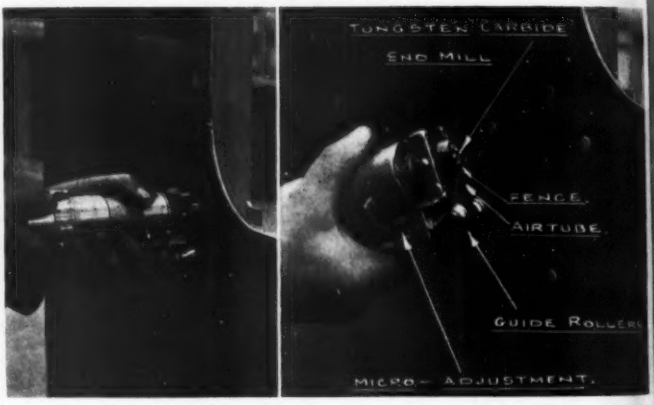
To obtain the flush finish on rivet heads used to secure the exterior cladding to the body framing of the lightweight diesel railcars now being built at the Derby Carriage and Wagon Works of British Railways, it was necessary to evolve a tool that would be light and portable in use and which would remove the excess head of the rivet with no damage to the surrounding panel. After some experimentation it was found that controlled vertical milling produced the best results.

The chief features of the machine are illustrated below and consist of a tungsten carbide end mill rotating within a guide or fence and mounted in an Armstrong Whitworth head secured to and driven by a Dessouter compressed air motor. A pair of adjustable guide rollers mounted on ball-bearings are fixed to the head and assist in propelling the tool over flat and curved panel surfaces. Compressed air is admitted to the motor by means of a spring-loaded push-button, this also allows a small quantity of air to be by-passed through a tube and blown across the cutters thus removing swarf.

Micrometer adjustment is provided to compensate for wear and re-grinding the cutting edges of the end mill.

Under actual working conditions about .015" of the rivet head projects above the panel after riveting, and this is milled away to leave about .001" for final dressing off by means of a small air-driven cone-shaped mounted stone.

The tool weighs about 3¾-lb. and is operated by air at a pressure of 90-lb. per sq. inch, rotating at approximately 4,000 r.p.m. It has proved to be eminently suited to work of this nature where an unblemished painted and varnished surface is the ultimate requirement.



S.C.I. CORROSION GROUP

ELECTION OF NEW COMMITTEE

THE Fourth Annual General Meeting of the Corrosion Group of the Society of Chemical Industry was held earlier this year in the rooms of the Chemical Society, Burlington House, with Dr. J. C. Hudson in the chair.

After the adoption of the committee's report on the activities of the past session, the chairman announced that Mr. T. H. Turner had accepted the committee's invitation to become chairman of the Group. The other honorary officers had been reappointed by the committee and a ballot was held to determine the election of three new members of the committee to fill vacancies due to retirement. Following the ballot the constitution of the committee for the coming session is as follows:

Chairman: Mr. T. H. Turner, *Vice-chairman:* Dr. J. C. Hudson, *Hon. Secretary:* Mr. S. C. Britton. *Hon. Treasurer:* Mr. W. E. Ballard, *Hon. Recorder:* Dr. P. T. Gilbert. *Committee:* Dr. F. A. Champion, Dr. S. G. Clarke, Dr. W. F. Higgins, Dr. T. P. Hoar, Mr. J. F. Kayser, Mr. L. Kenworthy, Mr. R. Ll. Rees, Mr. C. E. Richards, Dr. F. Wormwell, Dr. W. H. J. Vernon, Mr. L. W. Stubbs.

TECHNICAL BOOKSHELF

Protective Coatings for Metals by R. M. Burns and W. W. Bradley. 2nd edition. Published by Reinhold Publishing Corp., New York and available in this country from Chapman and Hall, Ltd., 37, Essex Street, Strand, London, W.C.2. Pp. 640. Price 96*s*. net.

THE first edition of this book, written by R. M. Burns and A. E. Schuh, has been, since 1939, a useful guide to users of protective coatings During its existence, the increased attention given to prevention of corrosion has yielded new coating processes and much more information about the performance of coatings of long standing. A new edition is therefore very welcome, the more so because the authors have clearly made a strong effort to bring their account up-to-date and to keep it fully representative of European as well as American thought. References to many papers published in 1953 and to some published in 1954 are included.

The general style and arrangement of the first edition have been retained but the thorough revision has, in accordance with developments, led to a fuller treatment of sprayed coatings and chemical conversion coatings. In addition, more space is devoted, with advantage, to the evaluation of organic coatings and a short chapter on corrosion inhibitors has been included. To those not familiar with the first edition, a brief outline of the arrangement will indicate the wide field covered. After an adequate introductory chapter on the principles of corrosion prevention, metal coatings are dealt with; a general account of coating processes is followed by detailed information about the various metallic coatings in use and by a chapter on methods of testing. Organic coatings are then dealt with on a similar plan and finally, chemical conversion coatings and miscellaneous, mainly special-duty, coatings are considered.

As the authors intended, the book is a work of reference for users of metal coatings rather than a guide to producers of coatings. There is however sufficient information about the production of coatings in the text to give the user an adequate understanding of how coatings are applied and the added references to literature show where more information is available. Some users may be disappointed that they cannot turn to the name of a particular article in the index and find immediately a recommendation of the best coating to apply to it. The effects of particular conditions on the relative merits of various coatings make any such general recommendations unwise and they have not been attempted. The information about performance of coatings in defined conditions is however clearly set out with ample references to original publications and the intelligent reader should have no difficulty in applying it to his own problems. He will also find excellent guidance to methods of testing.

The only notable gap is a lack of special reference to packaging and storage of coated parts; there are references to some storage troubles and to the use of vapour phase inhibitors and inhibitive wraps for steel, but a complete survey would have been welcome. The chapter on metal spraying could, with advantage, have been expanded to include more information about British developments; this, considered with the test results that are quoted would have enabled a rather less cautious view of the potentialities of sprayed coatings to be taken. Vitreous enamelling also might have been given fuller treatment; its widespread use seems to justify rather more than a relatively short section in the chapter on "Coatings for Special Duty." In general, however, the space devoted to the various coatings reflects the amount of information published about them and therefore a large allocation is made to zinc coatings and organic coatings.

The book is well printed, has a good index and carries abundant references to the literature. It can be thoroughly recommended to both users and producers of protective coatings.

S. C. BRITTON.

Electroplating Engineering Handbook. Edited by A. K. Graham. Published by Reinhold Publishing Corp., New York and available in this country from Chapman and Hall, Ltd., 37, Essex Street, Strand, London, W.C.2 Pp. 650. Price 80*s*. net.

CARLYLE once remarked "Life is a wonderful school but the fees are rather high." The same might be said of practical (as distinct from theoretical) experience as a tutor, especially when the subject of study involves factory plant handling corrosive solutions.

Everyone concerned with running an electroplating shop has at some time to consider the design and layout of the necessary plant and equipment. The easy way out, of course, is to put the whole problem into the hands of

supply houses and leave it at that. But this is not always satisfactory because however conscientious the suppliers may be, they can never be fully conversant with all the small detailed problems which concern a particular customer whether the latter be a jobbing plater or a large manufacturer using electro-chemical finishes as one of a chain of processes. It is far more satisfactory for the plater to attempt some sort of design of a plant so that when the supply house is called in, discussions with their representatives have the maximum utility and give both sides the fullest appreciation of the other's problems and a complete interchange of ideas. In some cases, especially for large plating shops it may even be preferable for the man responsible for running the shop to draw up very comprehensive plans of new or modified plant, and to have the equipment made as individual items to his own design.

The problems facing a designer of plant, whether he is a plating shop manager or a supply house engineer, can to a very great extent be thought out and the solutions arrived at from first principles. Nevertheless, as is commonly said, an ounce of experience is worth a pound of theory, and a plating shop manager may have fairly good ideas about the materials of which he would like his plant to be constructed, but not realise the difficulties of manufacture and therefore the impossibility of achieving his ideas completely. At all stages in design from broad outline to the fine details, therefore, discussions with experts in various fields are desirable, and indeed essential. The difficulty is finding competent counsellors to whom one may go for advice. Hence, the Electroplating Engineering Handbook will be a source of great comfort to those concerned with plant design and layout since it provides in one volume the cumulative experience and advice of 43 American experts in various fields of electroplating.

The book is divided into two parts—General Processing Data and Engineering Fundamentals and Practice. The first part, in fifteen chapters, discusses the more fundamental aspects of plating and surface preparation, generally without going into very extensive discussions of the plant required. The second part consists of a series of more

(*Continued in following page*)

AUTOMATIC CONTROL IN THE PROCESS INDUSTRIES

Joint Conference in October

A joint conference of the Institution of Chemical Engineers and The Society of Instrument Technology on "Automatic Control in the Process Industries" will be held in the Grand Hall, Caxton Hall, London, S.W.1. on October 4.

The conference will cover a number of aspects of automatic control in relation to the design and operation of process plant. Particular emphasis will be laid on the presentation of data in relation to practical installations and applications, without undue comment on instrument design or construction.

Persons interested in receiving full details of this conference should communicate with The General Secretary, The Institution of Chemical Engineers, 56, Victoria Street, S.W.1.

TECHNICAL BOOKSHELF

(*Continued from previous page*)

detailed discussions of the actual plating plant and buildings in which it is housed. The review is so comprehensive (it covers, for example, floors, tanks, linings, heating and cooling, jig design, layout of complete manual and automatic installations, exhaust systems, electrical supply and maintenance) that a complete novice might, after very thorough and careful study of the book, be able to design, build and operate a reasonably satisfactory shop. A little more detailed information on some particular points would be welcome, especially for example, in the plastic lining of tanks. It is an art at which both the Americans and engineers on the Continent appear to be very proficient but one which British tank manufacturers do not yet appear to have mastered completely. Many valuable tables of data are included and the book will be much used by experienced platers for reference—a use aided by a comprehensive index.

This is a well produced book in every way. It should not be difficult for every plating shop superintendent to manage to read ten pages or so of the book every day and the small amount of effort involved would be amply repaid. D. N. LAYTON

American Standards Progress

58th Annual Meeting of A.S.T.M.

WITH a near-record registered attendance of 2,537, exceeded only by the 50th Anniversary Meeting in New York with 2,602 in attendance in 1952, the American Society for Testing Materials brought to a close its 58th Annual Meeting at Atlantic City, N.J., on July 1. During the week's meeting, the Society held 32 Technical Sessions and approximately 700 technical committee meetings.

Sixty-six of the Society's technical committees presented reports. Sixty-seven new specifications and methods of test were approved as tentative, and revisions in 351 existing tentatives and standards were acted upon. A total of 119 specifications and methods of test previously designated as tentative were approved for reference to Society letter ballot for adoption as standard.

C. H. Fellows, Director, Engineering Laboratory and Research Dept., Detroit Edison Co., was elected President of the Society for a one-year term.

Among the reports considered were several dealing with subjects related to metal finishing and some of these are briefly reviewed below.

Electrodeposited Metallic Coatings

Although Committee B-8 did not meet during the Annual Meeting, a number of revisions and tentatives of standards were submittted for Society approval. Changes in Tentatives A166 (nickel and chromium on steel), B200 (lead on steel), and B201 (chromate finishes on zinc) are based on the definition of significant surfaces and should serve to prevent arguments on this subject which have arisen in the past. Standard A164 (zinc on steel), A165 (cadmium on steel), B141 (nickel and chromium on copper) and B142 (nickel and chromium on zinc) have been revised to indicate that "wherever possible thicknesses should be measured by magnetic methods on the maximum number of samples practicable since such measurements are non-destructive and inexpensive." The Recommended Practice for Chromium Plating on Steel for Engineering Use, B177, has had a cautionary note added pointing out that plated parts subject to alternating stresses or designed on the basis of fatigue characteristics should not be baked as baking generally tends to reduce the fatigue strength.

The committee is planning a "Symposium on Properties, Tests, and Performance of Electrodeposited Metallic Coatings" to be given at the Spring Meeting in Buffalo in February, 1956. The Symposium will be repeated at the ASTM Pacific Area National Meeting in Los Angeles in September, 1956.

Advisory Committee on Corrosion

Representation on the Advisory Committee on Corrosion is increasing as additional technical committees of the Society are becoming interested in corrosion and deterioration of metals and other materials subjected to atmospheric exposure. Within the past year, representatives from Committee C-22 on Porcelain Enamel, Committee A-3 on Cast Iron, and Committee A-7 on Malleable-Iron Castings have been added to the committee.

F. L. LaQue who has had to relinquish his position as chairman due to the pressure of increased responsibilities within his own company has been replaced by Jerome Strauss of the Vanadium Corp.

Corrosion of Iron and Steel

Committee A-5's wire and fence tests are now approaching 20 years of exposure to the atmosphere and data from the 1953 and 1954 inspections at 11 sites were reported. Extent of corrosion is measured by weight losses and by visual examination of all specimens and by tension tests on wire specimens.

Annual rate of loss of zinc coating ranges from 0.369 oz. per sq. ft. of surface at Pittsburgh, Pa., to 0.060 oz. per sq. ft. at State College, Pa.

It is of interest to note that chromium steel wires at Lafayette, Ind., corrode differently from those at other sites in that they have a mottled appearance and tiny spots of red rust scattered over their surfaces.

Corrosion of non-ferrous Metals and Alloys

In addition to sponsoring the Symposium on Corrosion of Non-Ferrous Metals and Alloys, Committee B-3 appended to its annual report a report summarizing the 20-year data on 24 non-ferrous metals and alloys.

Preliminary results of the programme aimed at calibrating the corrosivity of the atmosphere at various test sites indicate that the weight losses resulting from one year's exposure of panels of zinc and steel will give a good idea of the relative corrosivity of the sites.

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